ACTIVE CONTROL OF A LARGE SPACE
STRUCTURE AS APPLIED TO THE
PHASE 1 CETF SPACE STATION

THESIS

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THESIS

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of the Air Force Institute of Technology
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Dale A. Cope

Table of Contents

List of Figures

Figure			Page

List of Tables

ABSTRACT

The major objective of this thesis is to apply a decoupled control technique to a specific space station model. The model is a finite element model of the Phase 1 Critical Evaluation Task Force (CETF) Space Station. The control technique allows for the active control of a large number of modes by using several decoupled controllers. The space station attitude control system provides attitude stabilization and disturbance rejection. Its performance is evaluated by the station's response to two disturbances - crew motion and shuttle docking.

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I. Introduction

As stated by Dahlgren and Taylor, (Ref 6) future space missions will require controlling spacecraft which are both large and flexible. The control of these spacecrafts require a number of technological advances. Many of these advances are the focus of principal activities in the space station program. The space station is characterized with designs providing for evolutionary growth, low life cycle cost, and user accommodation. Some of the physical factors considered in the evolutionary process for a space station are:

1. Increasing Orbital Mass
2. Migrating Center-of-Gravity Locations
   - o Station buildup
   - o Change-out of major elements (solar arrays, radiators)
3. Varying Aerodynamic and Gravity-gradient Torques
   - o Orbit reboost
4. Changing Structural Rigid Body and Flexible Modes
   - o Station buildup
   - o Docked orbiter/orbit transfer vehicle
   - o Mass transfer of fuel/supplies
5. Astronaut/Construction Movements

These physical factors seriously impact the performance and operation of the space station's control system.

The limited natural damping and the uncertain and changing dynamic characteristics of vehicles, such as the manned space

station, will lead to unprecedented interaction between control and the structure. The major problems that causes this interaction are given in reference 6 as:

- o Low frequency and dense, closely coupled modes
- o Uncontrolled degrees of freedom
- o Unknown structural damping
- o Deployment dynamics and reliability
- o Identification of system parameters
- o Distortion, deflection, and recovery requirements
- o Nonlinear dynamic behavior

New control theories, sensors, and actuators must be able to achieve and maintain the required performance. For those systems that require high performance, control design techniques must address model spillover, be robust, and sometimes be adaptive. The interaction between control and the structure and the performance requirements make modern control theory with distributed control highly desirable if not mandatory. Distributed control theory is the theory for systems requiring spatially distributed multi-point sensing and actuation.

A key consideration for future space initiatives is the technology for controlling the attitude and dynamic deformations of large space structures. Active control of space structures deals with the active suppression of the space structure responses. (Ref 6) Calico, et. al. developed a decoupled control technique for controlling a large number of modes. This technique divides the structural modes into subsets and assigns these subsets to several decoupled controllers. The individual control

systems for the individual subsets are designed separately. This technique allows for the active control of a large number of modes without any one sub-controller exceeding a prescribed size. (Ref 3) In general, the control system must be able to increase the vibrational damping of the structure two or three times above the natural damping. (Ref 6)

The major objective of this thesis is to apply the decoupled control technique to a specific space station model. The model is a finite element model of the Phase 1 Critical Evaluation Task Force (CETF) Space Station proposed by the Structures and Mechanics Division at NASA's Johnson Space Center. Because of the large size of the model, the controller design must be performed on a truncated model for the structural dynamics. Reference 12 discusses various methods for determining an effective reduced order model of the dynamics. For this study, the truncation of modal coordinates is based on frequency and bandwidth considerations. A control system consisting of three decoupled controllers is applied to the reduced order model.

The decoupled control technique is used to analyze the motion and control requirements of the space station. The technique partitions the modes into controlled and residual state variables that model the equations of motion of the flexible body. The criteria for partitioning the modes is based on relative modal residues. The analysis uses these variables in a modal form of the equations of motion. The actuators are modeled as a forcing function on the space station. Using a transformation technique, the multiple controllers are decoupled from each other, and the

requirement for sensors and actuators can be determined. In designing the control system, point force and torque actuators provide the state variable feedback control. Position sensors are used to determine the modal amplitudes. (Ref 1)

The space station attitude control system provides attitude stabilization and disturbance rejection. Its performance is evaluated by eigenvalue analysis of the closed loop system and by the station's response to disturbances. Response to initial attitudes of 0.001 rad are evaluated along with response to initial attitude rates of 0.0001 rad/sec. Also, disturbances due to crew motion and shuttle docking are considered in the evaluation. (Ref 4)

In this thesis, an active control system is designed and applied to the Phase I CETF Space Station model. Section II describes in detail the finite element model of the space station. Section III develops the system model including the equations of motion and the decoupled control. Section IV presents the design of the control system. Section V investigates the design and presents the results of its performance. Section VI presents the conclusions and recommendations. The Appendices contain the eigenvectors and mode shapes of the space station model.

II. Model Configuration

This section describes the finite element model of the Phase 1 Critical Evaluation Task Force (CETF) Space Station, shown in Figure 1. The model represents the space station when it is first capable of being permanently manned. The full truss structure model, shown in Figure 2, identifies critical truss nodes and members. Figure 3 indicates the 31 critical truss nodes, and Figure 4 shows the space station subsystems. Shown in Figure 2, the origin of the station's coordinate system is at the geometric center of the power boom. The x-axis is in the flight direction, the z-axis is in the positive vertical, and the y-axis points along the port power boom completing this right-handed coordinate system. Table I shows the coordinates of the critical truss nodes.

The truss members are graphite epoxy tubes that are two inches in diameter and 0.06 inches thick. They have an overall Young's modulus of 15 million psi. The possible nonlinear characteristics of the truss joints were not modeled. The truss joints were assumed to be continuations of the graphite tubes. The truss configuration is based upon the Langley truss beam configuration. This truss pattern has all diagonal battens in the same plane. The alpha joint is modeled as having the same axial and torsional stiffness as the five meter truss, but only twenty percent of the bending stiffness. These stiffness parameters are based upon a Rockwell trade study. These parameters also produce an alpha joint with the same bending stiffness as the nine foot Langley truss beam.

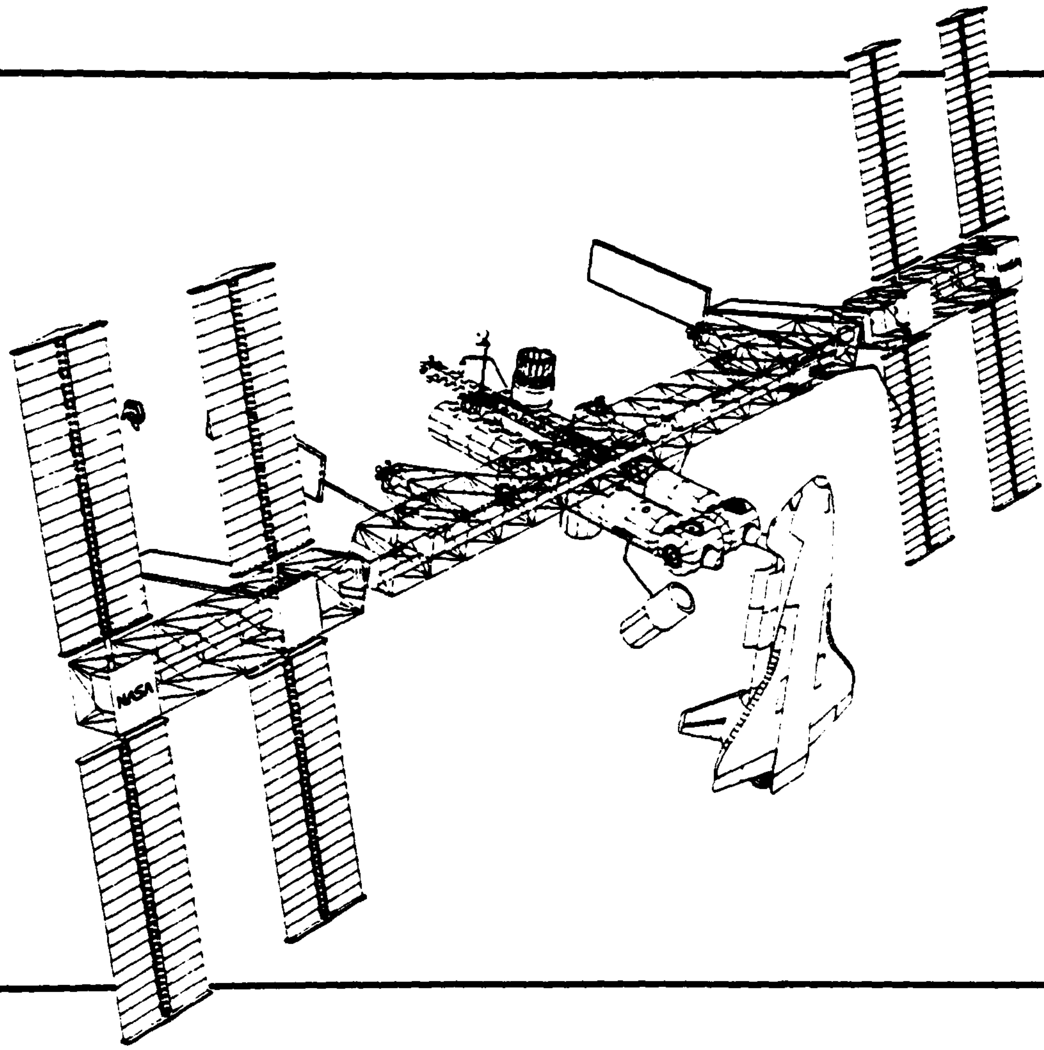


Figure 1. Phase 1 CETF Space Station

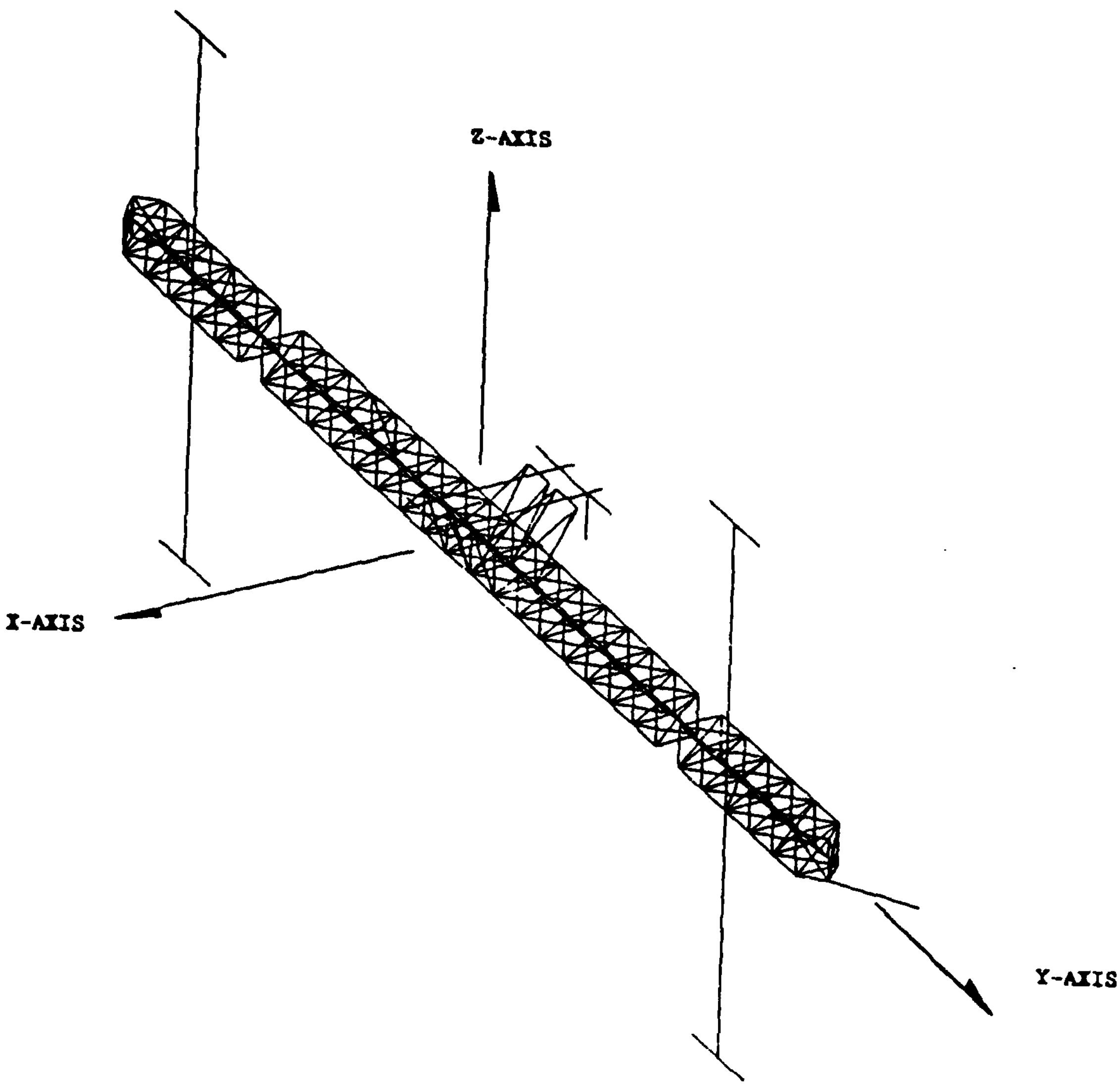
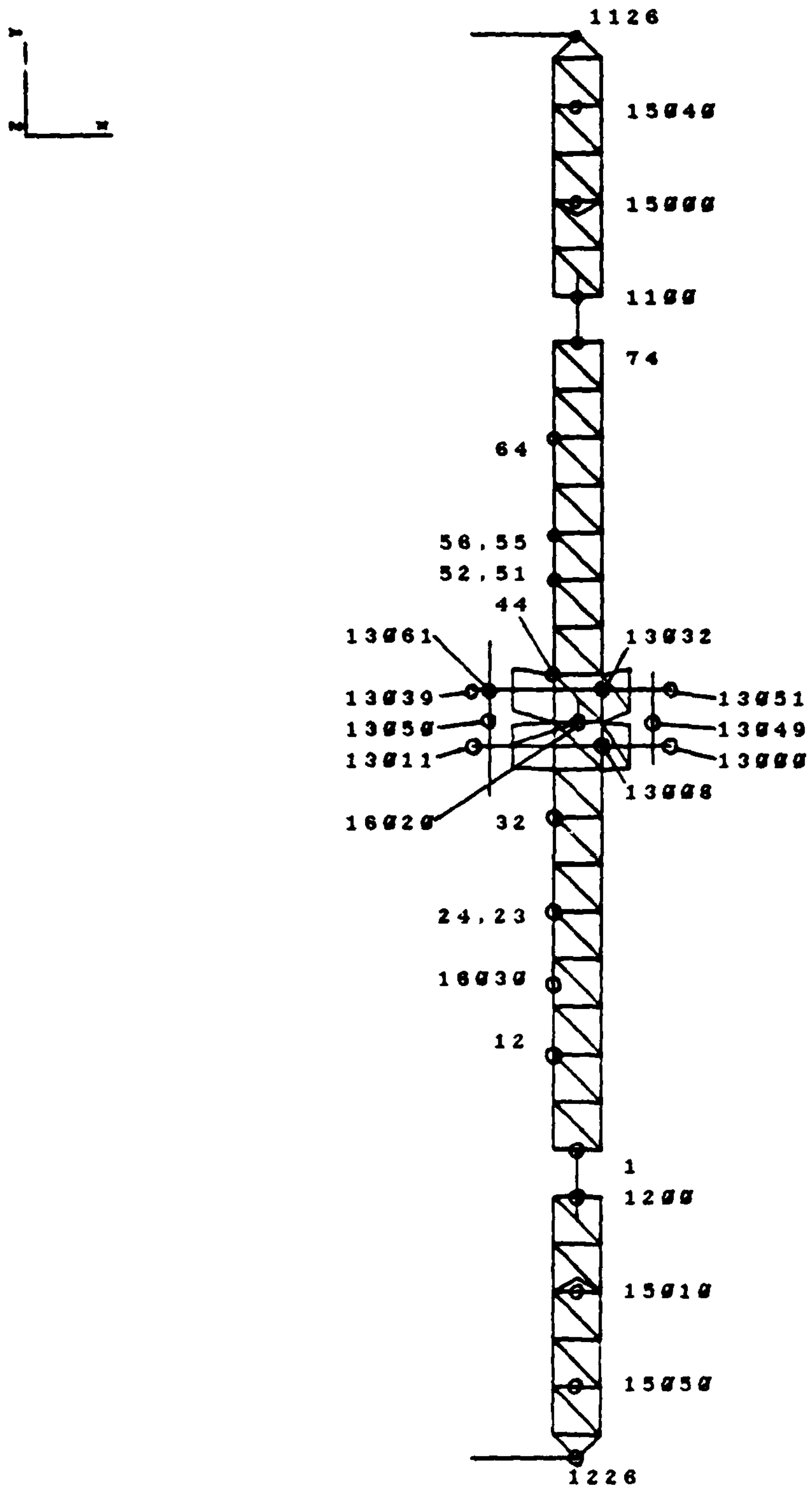


Figure 2. Finite Element Model of the Phase 1 CETF Space Station



Note: Grid ID's nearest the truss are on the back face of it

Figure 3a. Critical Truss Nodes of the Phase 1
CETF Space Station Model: TOP VIEW

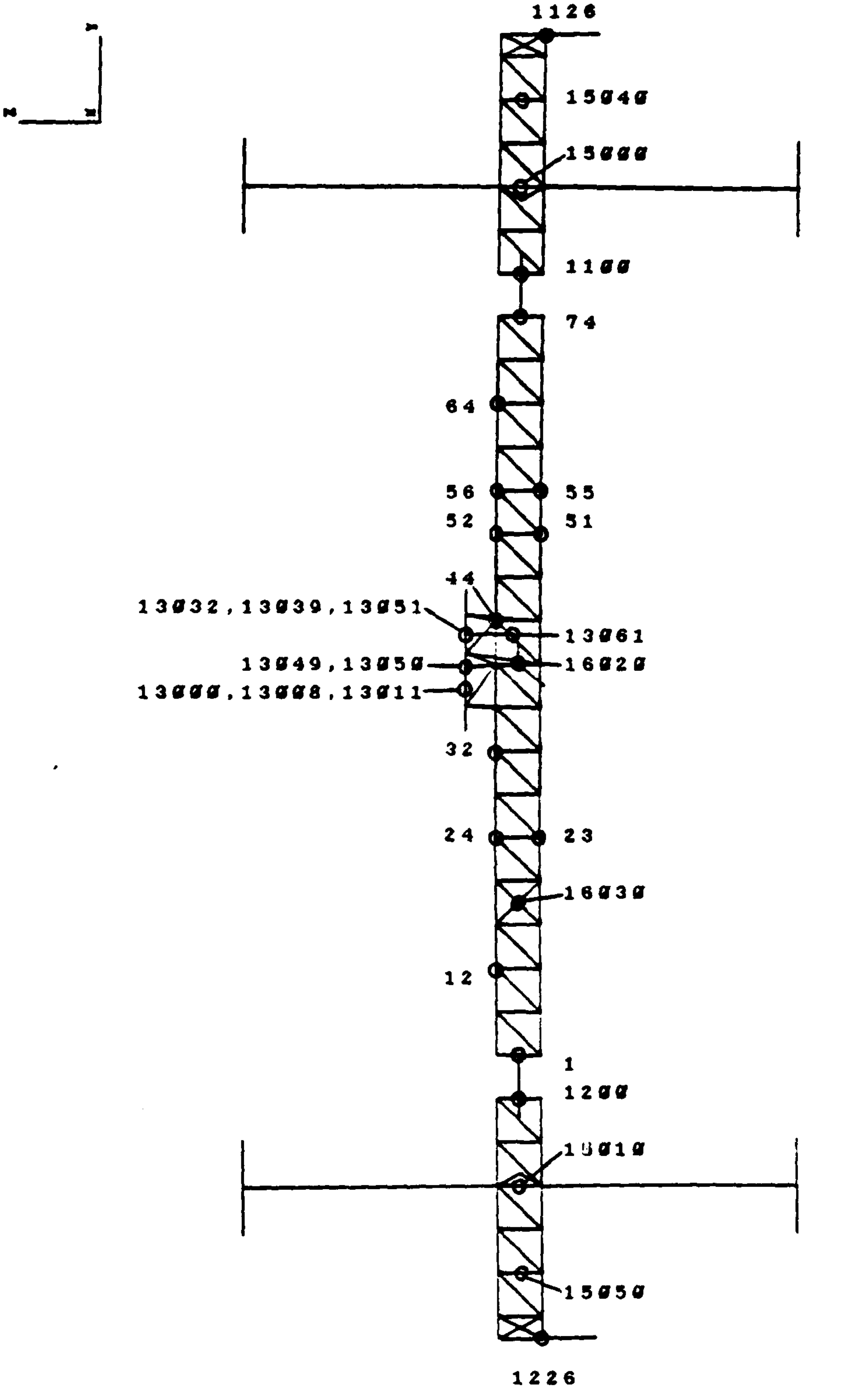


Figure 3b. Critical Truss Nodes of the Phase 1 CETF Space Station Model: FRONT VIEW

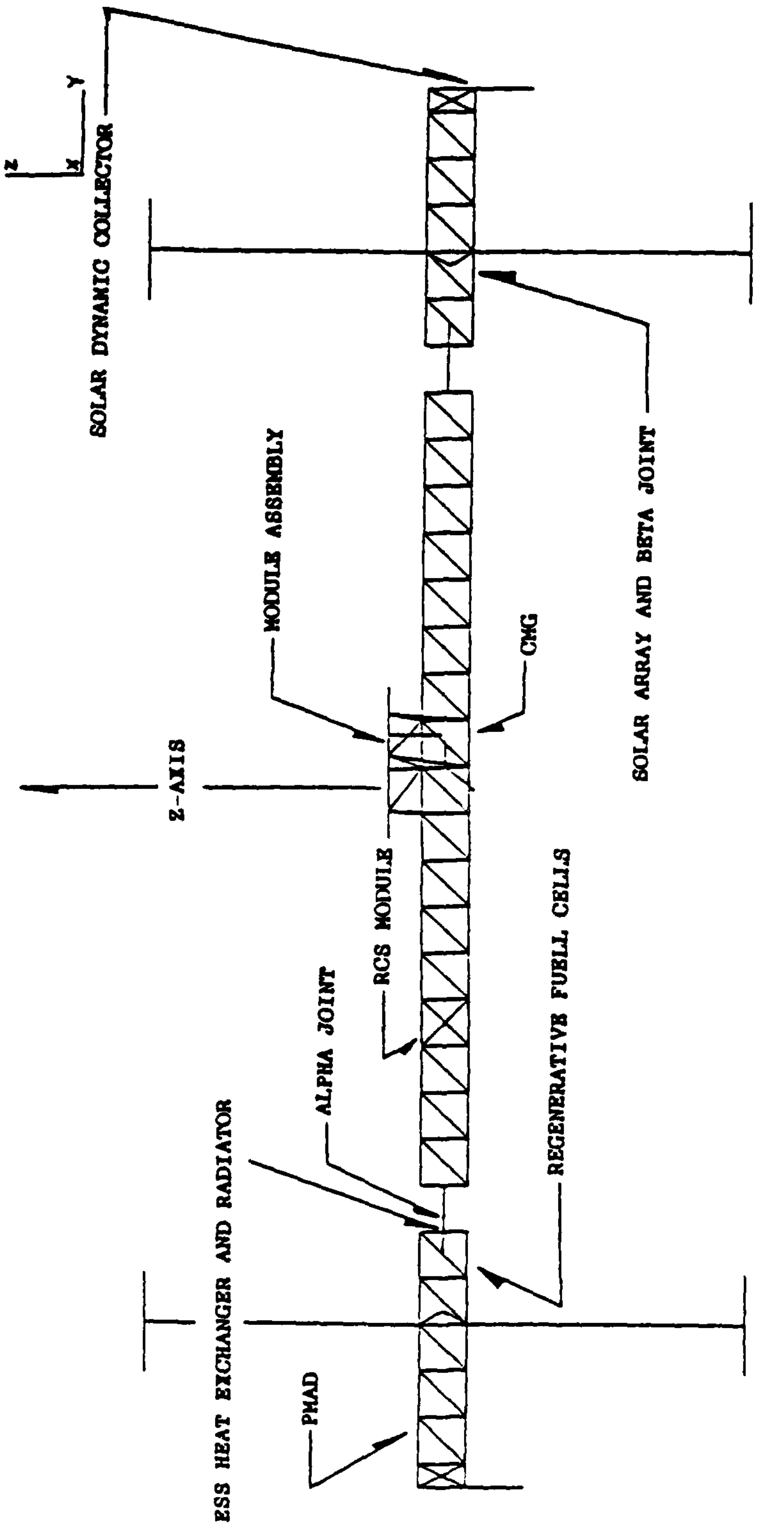


Figure 4. Phase 1 CETF Space Station Subsystems

NODE	X	Y	Z
1126	0.000	246.058	-8.202
15040	0.000	221.454	0.000
15000	0.000	183.750	0.000
1100	0.000	155.838	0.000
74	0.000	139.366	0.000
64	-8.202	106.626	8.202
55	-8.202	73.818	-8.202
56	-8.202	73.818	8.202
51	-8.202	57.414	-8.202
52	-8.202	57.414	8.202
13032	3.340	19.500	19.502
44	-8.202	24.606	8.202
16020	0.000	8.202	0.000
13008	3.340	0.000	19.502
32	-8.202	-24.606	8.202
23	-8.202	-57.414	-8.202
24	-8.202	-57.414	8.202
16030	-8.202	-82.020	0.000
12	-8.202	-106.626	8.202
1	0.000	-139.434	0.000
13051	31.840	19.500	19.502
13049	25.840	9.750	19.502
13000	31.840	0.000	19.502
13011	-36.660	0.000	19.502
13050	-30.660	9.750	19.502
13039	-36.660	19.500	19.502
13061	-30.660	19.500	1.402
1200	0.000	-155.838	0.000
15010	0.000	-183.750	0.000
15050	0.000	-221.454	0.000
1226	0.000	-246.060	-8.202

Table I. Coordinates of the Critical Truss Nodes (Feet)

Flexible appendages such as radiators, solar arrays, and solar dynamic collectors were modeled as rigid bodies. It was assumed that the vibrational characteristics of these subassemblies would not appreciably affect the modal characteristics of the overall station structure. Including these subassemblies would increase the density of the frequencies because their natural modes are close to the lower modes of the station. Also, their symmetry and multiplicity in the geometric configuration of the station would contribute to densely packed frequencies.

The module assembly was modeled with massless beam elements having the equivalent stiffness of the modules, nodes, and tunnels respectively. Concentrated masses having the appropriate inertias located at the geometric center of the beams accounts for their respective mass and inertia. The attachment of the module assembly to the truss structure of the station was modeled as follows. Struts run from the trunnion fittings on the modules to the nearest truss joints, and they are assumed to be rod elements having the same axial stiffness as the truss members. Individual modules were deterministically attached to the truss. Since the struts are rods, no moment is applied to the module trunnion fittings or to the points where the struts attach to the truss nodes. Mass of the electrical, heating, and other plumbing around the station was included in one truss node per truss bay. Satellite servicing hangars, stellar payloads, solar payloads, and Earth pointing payloads are not included. Table II shows the mass and inertia properties of the station.

Total Mass
7470 slugs (240,500 lbs mass)

Center of Mass
$x = -8.16$ ft., $y = 8.57$ ft., $z = 12.57$ ft.

Inertia Properties

$I_{xx} = 4.14 \times 10^{7}$ slugs-ft^2	$I_{xy} = -3.06 \times 10^{5}$ slugs-ft^2
$I_{yy} = 3.75 \times 10^{6}$ slugs-ft^2	$I_{xz} = 3.18 \times 10^{5}$ slugs-ft^2
$I_{zz} = 4.27 \times 10^{7}$ slugs-ft^2	$I_{yz} = 4.40 \times 10^{4}$ slugs-ft^2

Table II. Mass and Inertia Properties of the Phase 1 CETF Space Station

Table III lists the natural frequencies of the first one hundred structural modes obtained from an eigenvalue analysis performed using NASTRAN. The eigenvectors can be represented by a three-dimensional array as shown in Appendix A where the eigenvectors are grouped under structural modes. Within each mode there are n horizontal rows representing n nodes. Each row consists of three linear and three angular displacements. Appendix A contains only the first thirty structural modes, and Appendix B shows the first twenty-four flexible modes graphically.

Mode	Frequency Rad/Sec	Mode	Frequency Rad/Sec	Mode	Frequency Rad/Sec	Mode	Frequency Rad/Sec
1	0.0000	26	4.6393	51	39.3320	76	66.0410
2	0.0000	27	4.7577	52	39.4030	77	66.7290
3	0.0000	28	4.9330	53	40.8330	78	67.6090
4	0.0000	29	5.3647	54	43.6210	79	70.2700
5	0.0000	30	6.1424	55	44.0740	80	70.6720
6	0.0000	31	11.3300	56	44.5880	81	71.1920
7	1.2270	32	12.0530	57	44.9560	82	71.9450
8	1.2676	33	13.2300	58	45.4270	83	72.5850
9	2.6254	34	13.4100	59	45.9660	84	73.2940
10	2.9046	35	15.0640	60	47.2530	85	74.1170
11	3.0932	36	15.5470	61	49.5750	86	74.2810
12	3.4876	37	19.1760	62	50.3680	87	76.4780
13	4.0991	38	19.7490	63	50.7600	88	77.3540
14	4.1242	39	20.1640	64	53.3350	89	79.3070
15	4.2836	40	20.7820	65	54.1430	90	82.5320
16	4.3068	41	21.1760	66	56.9850	91	85.5320
17	4.3137	42	21.4520	67	59.3660	92	86.2460
18	4.3363	43	26.7550	68	60.7630	93	87.6910
19	4.3700	44	28.9940	69	61.3170	94	90.2300
20	4.3918	45	29.5430	70	62.9870	95	92.1180
21	4.4085	46	31.5580	71	63.5340	96	93.8980
22	4.4152	47	32.7070	72	64.5130	97	94.4580
23	4.4321	48	34.0150	73	64.9640	98	99.4830
24	4.4727	49	35.2150	74	65.1390	99	102.1000
25	4.6271	50	38.0160	75	65.9100	100	103.8000

Table III. Natural Frequencies of the Phase 1 CETF Space Station Model

III. System Model

Before successful control system design can proceed, appropriate mathematical models must be obtained for the attitude dynamics of the vehicle. The modeling involves understanding and extracting the essential features of the physical system. The techniques described in this section provide the necessary analytical model for use in the design of the space station attitude control system. (Ref 4)

Equations of Motion

Representation of spacecraft dynamics for a large space structure are normally based on a finite element model in the form

$$[M]\,\ddot{\bar{x}} + [K]\,\bar{x} = D\bar{u} \qquad (1)$$

where

$[M]$ = n x n symmetric mass matrix

$[K]$ = n x n symmetric stiffness matrix

D = n x m actuator influence coefficient matrix

$\bar{x}$ = n x 1 vector of generalized element displacements

$\bar{u}$ = m x 1 control input vector

Equation (1) can be decoupled by employing the similarity transformation $\bar{x} = \Phi\bar{\eta}$ such that

$$\Phi^T[M]\Phi = [I] \quad \text{and} \quad \Phi^T[K]\Phi = [\Omega^2]$$

where

Φ = n x n modal matrix whose columns are the structural mode shapes (eigenvectors)
$[I]$ = n x n identity matrix
$[\Omega^2]$ = n x n diagonal matrix of the natural frequencies squared (eigenvalues)

Substituting $\bar{x} = \Phi\bar{\eta}$ into Equation (1) and pre-multiplying by Φ^T, the equivalent modal representation becomes

$$\ddot{\bar{\eta}} + [\Omega^2]\,\bar{\eta} = \Phi^T D\bar{u} \qquad (2)$$

These equations of motion are independent since $[\Omega^2]$ is a diagonal matrix. The modal equations of motion can be reduced to first-order ordinary differential equations by defining

$$\bar{z}^T = (\bar{\eta}^T,\ \dot{\bar{\eta}}^T)$$

Equation (2) can then be written in the state space form:

$$\dot{\bar{z}} = A\bar{z} + B\bar{u} \qquad (3)$$

where

$$A = \left[\begin{array}{c|c} \emptyset & [I] \\ \hline -[\Omega^2] & \emptyset \end{array}\right] \quad \text{and} \quad B = \left[\begin{array}{c} \emptyset \\ \hline \Phi^T D \end{array}\right]$$

For a finite number of ideal position and velocity sensors, the response vector $\bar{y}$ is given by

$$\bar{y} = Cp\ \bar{x} + Cv\ \dot{\bar{x}} = Cp\Phi\bar{\eta} + Cv\Phi\dot{\bar{\eta}} \quad \text{or} \quad \bar{y} = C\ \bar{z} \qquad (4)$$

where $C = [Cp\Phi \mid Cv\Phi]$. The matrices Cp and Cv define the location and orientation of the position and velocity sensors, respectively. (Ref 12)

Decoupled Control

As shown by Aldridge, the space station model is represented by the 2n-dimensional state vector $\dot{\bar{z}}$. It is not possible to control all the modes for this complex structure. Therefore, assuming that multiple controllers are available, each controlling n_i modes, the state vector $\bar{z}$ is simply represented by

$$\bar{z}^T = \{\bar{z}_1{}^T,\ \bar{z}_2{}^T,\ \ldots,\ \bar{z}_N{}^T,\ \bar{z}_r{}^T,\ \bar{z}_{um}{}^T\} \qquad (5)$$

The $\bar{z}_i$ represents a $2n_i$-dimensional vector of the modal amplitudes

and velocities controlled by the ith controller. $\bar{z}_r$ represents a $2n_r$-vector of residual modes modeled in the structure but not controlled. $\bar{z}_{um}$ represents a vector of modes that are not modeled in the control system design. These modes in $\bar{z}_{um}$ are truncated from the model so they will no longer appear in the derivations. Now, the control system model is

$$z^T = (z_1{}^T, z_2{}^T, \ldots, z_N{}^T, z_r{}^T) = (z_c{}^T, z_r{}^T) \qquad (6)$$

where the controlled state, $\bar{z}_c$, is that portion of the modes which require active control to insure satisfactory system performance. The selection of the modes to be controlled and their assignment to one of the N controllers is at the discretion of the control designer. (Ref 1)

The notation of Eq. (6) may be used to express the state equations in the following form:

$$\dot{\bar{z}}_i = A_i \bar{z}_i + B_i \bar{u} \qquad i = 1, 2, \ldots, N, r \qquad (7)$$

The output equation has the form

$$\bar{y} = \sum_{i=1}^{N} C_i \bar{z}_i + C_r \bar{z}_r \qquad (8)$$

The A, B, and C matrices are

$$A_i = \left[\begin{array}{c|c} \emptyset & [I] \\ \hline -[\Omega_i{}^2] & -[2\zeta\Omega_i] \end{array}\right], \quad B_i = \left[\begin{array}{c} \emptyset \\ \hline \Phi^T D_i \end{array}\right], \qquad (9)$$

$$C_i = [Cp_i\Phi \mid Cv_i\Phi] \qquad i = 1, 2, \ldots, N, r$$

Modal damping has been added to the matrices A_i. For preliminary analysis and design, a constant damping ratio of Ø.5% in modal coordinates is assumed for a conservative design. The non-zero partitions of the matrices B_i have dimensions $n_i \times n_a$, and the

partitions of the C_i are of dimension $n_S \times n_i$ where n_a and n_S are the number of actuators and number of sensors, respectively. (Ref 3) The rows of the $\Phi^T D_i$ matrices represent the amplitude of each structural mode along the line of action of each actuator location. In this study, only position sensors are used; therefore, the Cv_i matrices are zero. The columns of the $Cp_i\Phi$ matrices represent the amplitude of each structural mode along the line of the sensor at each sensor location. For collocated sensors and actuators, $Cp_i = D_i^T$ so $Cp_i\Phi = (\Phi^T D_i)^T$. (Ref 1)

Modal Control

The controller design for N controllers is based upon the state equations of motion given by Eqs (7) and (8). The form of the desired state feedback control is

$$\bar{u} = \sum_{i=1}^{N} G_i \bar{z}_i \tag{10}$$

where G_i are the controller gain matrices. To form this active control $\bar{u}$, complete knowledge of the state vector is needed. However, the only measure of $\bar{z}$ is the measurement $\bar{y}$ given by the sensors. Therefore, the control implementation requires the construction of an observer to estimate the modal coordinates. The observer has the form

$$\dot{\hat{z}}_i = A_i \hat{z}_i + B_i \bar{u} + K_i(\bar{y} - \hat{y}_i) \tag{11}$$

$$\hat{y}_i = C_i \hat{z}_i \tag{12}$$

where $\hat{z}_i$ are the estimated states, $\hat{y}_i$ are the estimated outputs, and K_i are the observer gain matrices. The K_i matrices are chosen such that the error in the state estimate

$$\bar{e}_i = \hat{z}_i - \bar{z}_i \tag{13}$$

is asymptotically stable. In terms of the estimated state, the control vector is given by

$$\bar{u} = \sum_{i=1}^{N} G_i \hat{z}_i \tag{14}$$

Equations (7), (8), (11), (12), and (14) represent the control problem for a large space structure.

To develop the controller gain matrices G_i and observer gain matrices K_i, linear optimal regulator theory (Ref 8) is used. The controller gain matrix G_i is selected to minimize a quadratic performance index J of the form

$$J = \frac{1}{2} \int_0^{\infty} (\bar{z}_i{}^T Q_i \bar{z}_i + \bar{u}^T R_i \bar{u})\, dt \tag{15}$$

where Q_i is positive semidefinite and R_i is positive definite. The gain matrix G_i is then

$$G_i = -R_i{}^{-1} B_i{}^T S_i \tag{16}$$

where S_i is the solution to the steady state matrix Riccati equation:

$$A_i{}^T S_i + S_i A_i - S_i B_i R_i{}^{-1} B_i{}^T S_i + Q_i = \emptyset \tag{17}$$

The observer gain matrices K_i are developed similarly since the eigenvalues of the matrix $(A_i - K_i C_i)$ are the same as the eigenvalues of its transpose $(A_i{}^T - C_i{}^T K_i{}^T)$. An equation for the system similar to Eq (7) can be written using the state $\bar{w}$:

$$\dot{\bar{w}}_i = A_i{}^T \bar{w}_i - C_i{}^T \bar{g}_i \tag{18}$$

where the $\bar{g}_i$ is the control input given by

$$\bar{g}_i = K_i{}^T \bar{w}_i \tag{19}$$

Again, using linear optimal regulator theory, the observer gain matrix is selected to minimize a quadratic performance index J_{ob}.

$$J_{ob} = \frac{1}{2}\int_{0}^{\infty}(\bar{w}_i^T Q_{obi}\bar{w}_i + \bar{s}^T R_{obi}\bar{s})\, dt \qquad (20)$$

The Q_{ob} and R_{ob} weighting matrices are also positive semidefinite and positive definite, respectively. However, they are not necessarily the same as the Q and R matrices. It may be desirable to weight the observation data more or less than the control feedback. Now, the observer gain matrix is given by

$$K_i = R_{obi}^{-1} C_i P_i \qquad (21)$$

where P_i is the solution to the steady state matrix Riccati equation:

$$P_i A_i^T + A_i P_i - P_i C_i^T R_{obi}^{-1} C_i P_i + Q_{obi} = 0 \qquad (22)$$

Note that Eq (22) is the transpose of Eq (17) since the observer gain matrix is developed from the transpose of the system matrix $(A_i - K_i C_i)$. (Ref 1)

Considering control for N individual systems of the form

$$\dot{\bar{z}}_i = A_i \bar{z}_i + B_i \bar{u} \qquad i = 1,2, \ldots, N, r \qquad (7)$$

$$\bar{y} = \sum_{i=1}^{N} C_i \bar{z}_i + C_r \bar{z}_r \qquad (8)$$

Eqs (16) and (21) form the controller gains G_i and the observer gains K_i to be used in their respective controllers. They are selected such that each controller is stable. However, the control $\bar{u}$ is the same control for each of the N systems, and the output $\bar{y}$ includes all of the original system modes. Therefore, the controllers are coupled together, and the overall system may be unstable. This coupling can be seen in the following

development of a three-controller system, and it is referred to as controller and observer spillover. The objective is to design the N controllers such that the spillover does not affect system stability. (Ref 3)

Three Controllers

For a multi-input, multi-output controller, the state equations are given by Eq (7). For N = 3, the state equations are

$$\dot{\bar{z}}_1 = A_1\bar{z}_1 + B_1\bar{u} \tag{23a}$$

$$\dot{\bar{z}}_2 = A_2\bar{z}_2 + B_2\bar{u} \tag{23b}$$

$$\dot{\bar{z}}_3 = A_3\bar{z}_3 + B_3\bar{u} \tag{23c}$$

$$\dot{\bar{z}}_r = A_r\bar{z}_r + B_r\bar{u} \tag{23d}$$

where the subscripts 1, 2, and 3 designate the equations describing the modes assigned to the ith controller and the subscript r denotes the equations describing the uncontrolled modes. The observer is

$$\dot{\hat{z}} = A_i\hat{z} + B_i\bar{u} + K_i(\bar{y} - \hat{y}_i) \qquad i = 1,\ 2,\ 3 \tag{24}$$

$$\hat{y}_i = C_i\hat{z}_i \qquad i = 1,\ 2,\ 3 \tag{25}$$

where the observer gain matrices K_i are chosen such that the errors in the state estimates,

$$\bar{e}_i = \hat{z}_i - \bar{z}_i \qquad i = 1,\ 2,\ 3 \tag{26}$$

are asymptotically stable. Now, the control

$$\bar{u} = G_1\hat{z}_1 + G_2\hat{z}_2 + G_3\hat{z}_3 \tag{27}$$

is applied. Equations (24), (25), and (26) may then be combined with equations (23) (a) through (d) to obtain the state estimate errors

$$\dot{\bar{e}}_1 = (A_1 - K_1C_1)\bar{e}_1 + K_1C_2\bar{z}_2 + K_1C_3\bar{z}_3 + K_1C_r\bar{z}_r \quad (28a)$$

$$\dot{\bar{e}}_2 = (A_2 - K_2C_2)\bar{e}_2 + K_2C_1\bar{z}_1 + K_2C_3\bar{z}_3 + K_2C_r\bar{z}_r \quad (28a)$$

$$\dot{\bar{e}}_3 = (A_3 - K_3C_3)\bar{e}_3 + K_3C_1\bar{z}_1 + K_3C_2\bar{z}_2 + K_3C_r\bar{z}_r \quad (28a)$$

Using the state equations given in Eq (23) along with the control stated in Eq (27), the controlled state equations are given by

$$\dot{\bar{z}}_1 = (A_1 + B_1G_1)\bar{z}_1 + B_1G_1\bar{e}_1 + B_1G_2\bar{z}_2 + B_1G_2\bar{e}_2 + B_1G_3\bar{z}_3 + B_1G_3\bar{e}_3 \quad (29a)$$

$$\dot{\bar{z}}_2 = (A_2 + B_2G_2)\bar{z}_2 + B_2G_2\bar{e}_2 + B_2G_1\bar{z}_1 + B_2G_1\bar{e}_1 + B_2G_3\bar{z}_3 + B_2G_3\bar{e}_3 \quad (29b)$$

$$\dot{\bar{z}}_3 = (A_3 + B_3G_3)\bar{z}_3 + B_3G_3\bar{e}_3 + B_3G_1\bar{z}_1 + B_3G_1\bar{e}_1 + B_3G_2\bar{z}_2 + B_3G_2\bar{e}_2 \quad (29c)$$

$$\dot{\bar{z}}_r = A_r\bar{z}_r + B_rG_1\bar{z}_1 + B_rG_1\bar{e}_1 + B_rG_2\bar{z}_2 + B_rG_2\bar{e}_2 + B_rG_3\bar{z}_3 + B_rG_3\bar{e}_3 \quad (29d)$$

These equations (29) (a) through (d) may be represented in the state-space form, $\dot{\bar{z}} = A\bar{z}$, by defining the controlled state vector:

$$\bar{z}_c{}^T = \{\bar{z}_1{}^T, \bar{e}_1{}^T, \bar{z}_2{}^T, \bar{e}_2{}^T, \bar{z}_3{}^T, \bar{e}_3{}^T, \bar{z}_r{}^T\} \quad (30)$$

Now, using Eq (30), the controlled state equations may be represented by

$$\dot{\bar{z}}_c = A_c\bar{z}_c \quad (31)$$

where

$$A_c = \begin{bmatrix} A_1+B_1G_1 & B_1G_1 & B_1G_2 & B_1G_2 & B_1G_3 & B_1G_3 & 0 \\ 0 & A_1-K_1C_1 & K_1C_2 & 0 & K_1C_3 & 0 & K_1C_r \\ B_2G_1 & B_2G_1 & A_2+B_2G_2 & B_2G_2 & B_2G_3 & B_2G_3 & 0 \\ K_2C_1 & 0 & 0 & A_2-K_2C_2 & K_2C_3 & 0 & K_2C_r \\ B_3G_1 & B_3G_1 & B_3G_2 & B_3G_2 & A_3+B_3G_3 & B_3G_3 & 0 \\ K_3C_1 & 0 & K_3C_2 & 0 & 0 & A_3-K_3C_3 & K_3C_r \\ B_rG_1 & B_rG_1 & B_rG_2 & B_rG_2 & B_rG_3 & B_rG_3 & A_r \end{bmatrix}$$

Transformation

The matrix A_C illustrates the coupling that causes the controller and observer spillover between the three controllers. As previously stated, this spillover may cause instability in the overall system. To eliminate the spillover terms from the controlled states, the following approach shown by Calico and Eastep is used. Define new control vectors $\bar{v}_i$ and new output vectors $\bar{\upsilon}_i$ by the following relationships:

$$\bar{u} = \sum_{i=1}^{3} T_i \bar{v}_i \qquad (32)$$

$$\bar{\upsilon}_i = \Gamma_i \bar{y} \qquad i = 1, 2, 3 \qquad (33)$$

where the transformation matrices T_i and Γ_i are chosen to eliminate the controller and observer spillover terms, respectively. Eq (32) is substituted into Eq (7) and Eq (8) is substituted into Eq (33) to obtain

$$\dot{\bar{z}}_i = A_i \bar{z}_i + B_i \left[\sum_{j=1}^{3} T_j \bar{v}_j \right] \qquad i = 1, 2, 3 \qquad (34)$$

$$\bar{\upsilon}_i = \Gamma_i \left[\sum_{j=1}^{3} C_j \bar{z}_j \right] \qquad i = 1, 2, 3 \qquad (35)$$

For coupled but stable operation of the three controllers, the matrices B_1G_2, B_1G_3, B_2G_3, K_1C_2, K_1C_3, and K_2C_3 are driven to zero by requiring that

$$B_i T_j = \emptyset \quad \text{and} \quad \Gamma_i C_j = \emptyset \qquad i = 1, 2 \; ; \; j = 2, 3 \qquad (36)$$

Letting $B_i^* = B_i T_i$ and $C_i^* = \Gamma_i C_i$, we have three decoupled relationships of the form:

$$\dot{\bar{z}}_i = A_i \bar{z}_i + B_i^* \bar{u} \qquad i = 1, 2, 3 \qquad (37)$$

with the decoupled outputs

$$\bar{U}_i = C_i^* \bar{Z}_i \qquad i = 1, 2, 3 \tag{38}$$

Eqs (37) and (38) may be used to design the three controllers so that they will not interact when operating simultaneously. (Ref 3) The transformation matrices T_i and Γ_i are obtained by using Singular Value Decomposition, and this development is discussed in more detail in reference 1. In the development, the additional constraint to the residual modes is ignored. For a sufficiently large controlled state $\bar{Z}_c$, the spillover should not be significant between the modes in the controlled state $\bar{Z}_c$ and the residual state $\bar{Z}_r$.

Sensor/Actuator Requirements

In order to perform spillover suppression, one or more gain matrices must be made orthogonal to N-1 B or C matrices. For example, to satisfy Eq (36), the columns of T_N must be orthogonal to the rows of B_1 through B_{N-1}. In other words, the columns of T_N must be in the span of the null space of the matrix B_{1N}, where:

$$B_{1N} = \begin{bmatrix} B_1 \\ \cdots \\ \vdots \\ \cdots \\ B_{N-1} \end{bmatrix} \tag{39}$$

If B_{1N} has full rank, the null space of B_{1N} has dimension:

$$P_{1N} = n_a - \sum_{i=1}^{N-1} n_i \tag{40}$$

Therefore, for the matrix T_N to exist, the number of actuators n_a must exceed the total number of modes controlled by the first N-1 controllers.

$$n_a > \sum_{i=1}^{N-1} n_i \qquad (41)$$

It can be shown that the other control gain matrices will have a sufficient number of actuators if the inequality in Eq (41) is met. That is, the other conditions involving T_1 through T_{N-1} can be met if inequality (41) is satisfied. A similar study shows the number of sensors needed in determining the Γ_i that satisfies Eq (36). This condition requires that the number of sensors be such that:

$$n_S > \sum_{i=2}^{N} n_i \qquad (42)$$

Examining Eq (32), the dimensions of $\bar{v}_N$ equals the dimension of the null space of B_{1N}. Without the transformation T_N, the control $\bar{u}$ has the dimension n_a. Similarly, the dimensions of the outputs of the individual system $\bar{v}_i$ are less than the dimension of $\bar{y}$. This is due to the dimensions of the matrices Γ_i. This loss in dimension is the price paid for the decoupling. (Ref 3)

IV. Control System Design

The space station requires an attitude control system that maintains orientation in all phases of construction, operation, and maintenance. The attitude control system must provide for disturbance rejection of crew motion and less frequent docking. (Ref 4) As stated, the control system design uses three controllers. Each controller is designed using full state feedback and a full state estimator. The controllers are decoupled from one another using the techniques previously discussed. Linear quadratic regulator theory is used to design both the controllers and the observers. The state weighting matrices used are identity matrices multiplied by a constant value of twenty. The control and observer weighting matrices are identity matrices. (Ref 3) Attitude control of the space station consists of attitude stabilization that maintains the desired attitude in the presence of short-term disturbance, e.g., crew motion with a characteristic time on the order of 100 seconds. The main design objective of the short-term controller is to provide the highest possible closed-loop bandwidth and to achieve reasonable rigid body damping while stabilizing all structural modes. (Ref 4)

Modal Selection

One of the more difficult tasks in controlling a large space structure is the determination of which structural modes should be considered in the control system design. It is important to ensure that all essential features of the physical system are

retained and the unmodeled parts do not interact with the controller to degrade performance or even drive the closed-loop system unstable. NASTRAN can produce hundreds of modes, but only the low frequency modes can be experimentally verified. Mode shapes are less reliable than mode frequencies due to numerical difficulties. Nonlinear characteristics in the structure and joints may make the calculation of higher modes meaningless. Control design techniques often experience numerical difficulty or become impractical when the model order is high. Equally important, a low order model encourages more direct understanding of the underlying physical system. All these suggest that the control engineer should work on low order models in the preliminary design stage. (Ref 4)

For lightly damped space structures with sufficient modal separation, modal truncation using different modal indices is equivalent to various model reduction approaches. Using the index of modal frequencies, the following factors are considered in the modal truncation to determine the frequency bandwidth of the attitude control system. In a Rockwell study on "Space Station Structural/Control Interaction", docking loads are affected by modes at 0.2105 Hz. (Ref 11) Also, the different concepts of the Crew and Equipment Translation Aid (CETA) operate at lateral vibrational frequencies of 0.543 Hz, 0.463 Hz, and 0.17 Hz. (Ref 15) These frequencies may lead to coupling of the CETA and the dynamics of the Space Station. Active stabilization of structural modes other than the lowest frequency mode is not used for two reasons. First, modes at frequencies above 1 Hz become

very difficult to stabilize for the following reason. The phase loss due to time delays at frequencies above 1 Hz becomes sufficiently large to render phase stabilization very difficult, if not impossible. Second, individually stabilizing many modes usually results in a controller which is highly tuned and extremely sensitive to plant variations. (Ref 4) Comparing the first fifty structural mode frequencies, shown in Figure 5, a large increase from 0.9776 Hz at mode 30 to 1.8033 Hz at mode 31 is noted. Since the structure's natural damping will normally

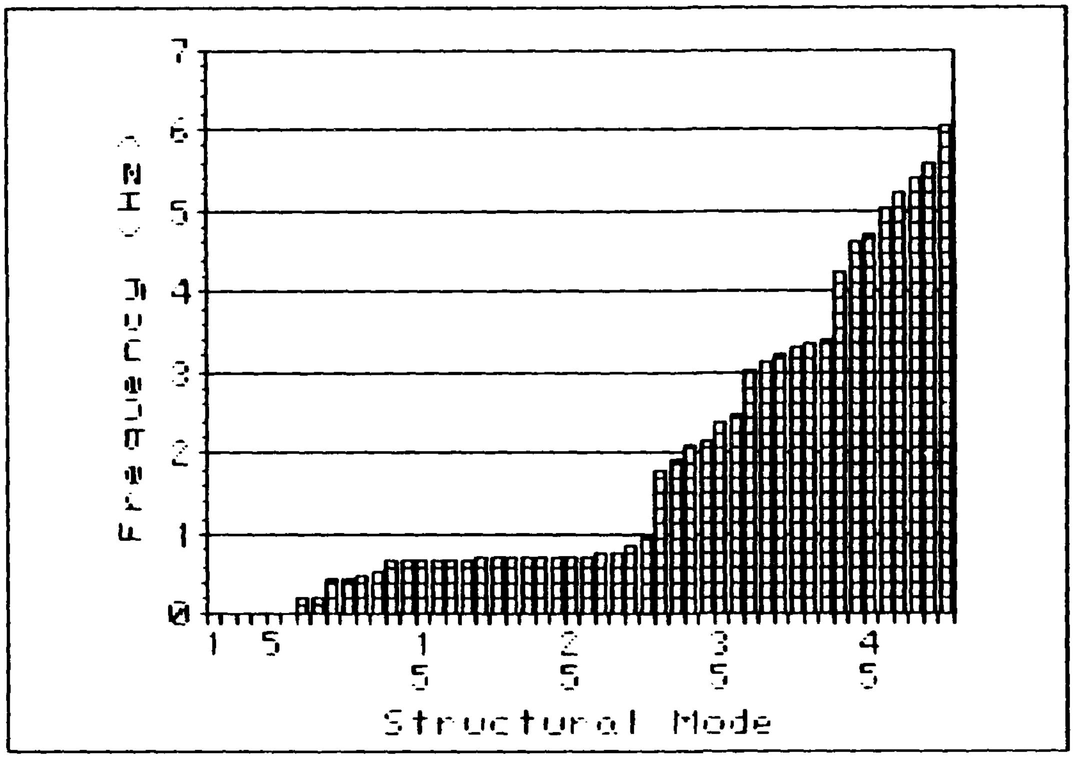


Figure 5. First 50 Structural Mode Frequencies

prevent instabilities arising from the higher frequency modes. the modes above 30 are truncated and left as unmodeled modes. Therefore, a frequency bandwidth of 1 Hz is chosen for the attitude control system, and only the first thirty structural

modes will be considered in the control analysis.

Actuator/Sensor Location

Many large space structures being considered by NASA require multiple sensors and actuators distributed *in some fashion* throughout the structure. (Ref 6) The location of sensors and actuators are important to the overall control system performance. The geometry has a major impact on the rigid-body mode behavior while structural compliance between actuators and sensors determines flexible mode behavior. (Ref 4) Therefore, one must consider the spatial distribution of sensors and actuators when treating the problem from a finite element approach. However, the trade-off process is a major spacecraft design issue and is not covered in this study.

Each sensor or actuator has to be attached to a node. The direction in which an actuator is aligned and the magnitude of its force or torque are expressed by $D\bar{u}$ in terms of x-y-z components. Force actuators use the first three columns of the eigenvectors, and torque actuators use the second three columns as shown in Appendix A since each node has six degrees of freedom. The alignment of a sensor is expressed in the matrix Cp. If a sensor or actuator is aligned with a coordinate axis, the corresponding element of $C_p\Phi$ or $\Phi^T D$ is simply the eigenvector element at that physical coordinate multiplied by a scale factor. Since the actuator bandwidth is significantly higher than the attitude control bandwidth, the actuator is treated as an *ideal* device in the preliminary design. For example, control moment gyros have a bandwidth in excess of 3 Hz. (Ref 4)

It is important to examine the geometry relations among sensors and actuators. A sensor and an actuator are collocated when they are located at the same node and aligned in the same direction. A gyro/torquer pair is a typical example. Note that a linear actuator and an angular sensor at the same location do not satisfy the definition of collocation. If a sensor and an actuator are separated by rigid structure, they can be considered collocated with some caution. When an actuator and a sensor are collocated on a free-free structure, the rigid body modes and all the flexible modes stably interact with each other. In general, actuator/sensor pairs are not collocated. (Ref 4)

To determine the actuator and sensor locations, the first twenty-four flexible modes (shown graphically in Appendix B) are examined. For each mode, relatively large translational and angular displacements of node points are noted. Then, the actuator and sensor locations are chosen to effectively correct these displacements. The number of sensors and actuators were kept to a minimum. Therefore, to satisfy the sensor/actuator requirement shown in Section III, sixteen pairs of collocated sensors and actuator are initially chosen. However, the structural damping was not improved on eight modes so eight more sensors were added. The locations are listed in Table IV and shown in Figure 6. Both force and torque actuators are used, but only position sensors are chosen.

Collocated Sensors and Actuators

Pair	Node	TX	TY	TZ	RX	RY	RZ	State Coordinate
1	1126	1	0	0	0	0	0	1
2	1126	0	0	1	0	0	0	3
3	15000	0	0	0	1	0	0	16
4	15000	0	0	0	0	0	1	18
5	64	1	0	0	0	0	0	31
6	64	0	0	1	0	0	0	33
7	56	0	0	0	1	0	0	46
8	56	0	0	0	0	0	1	48
9	24	0	0	0	1	0	0	100
10	24	0	0	0	0	0	1	102
11	12	1	0	0	0	0	0	109
12	12	0	0	1	0	0	0	111
13	15010	0	0	0	1	0	0	172
14	15010	0	0	0	0	0	1	174
15	1226	1	0	0	0	0	0	181
16	1226	0	0	1	0	0	0	183
Additional Sensors								
1	1100	1	0	0	0	0	0	19
2	1100	0	0	1	0	0	0	21
3	56	1	0	0	0	0	0	43
4	56	0	0	1	0	0	0	45
5	24	1	0	0	0	0	0	97
6	24	0	0	1	0	0	0	99
7	1200	1	0	0	0	0	0	163
8	1200	0	0	1	0	0	0	165

Note: The orientations are given in terms of direction cosines

Table IV. Actuator/Sensor Locations and Orientations on the Phase 1 CETF Space Station Model

Modal Assignment

Modal residues are used as a measure to determine which modal states to consider as controlled states and as residual states. The modal residue represents the contribution of a mode to the input-output transfer function. If a mode has a very small residue, it has a very small contribution to an input-output relation. Therefore, the mode can be removed from the transfer function with hardly any impact. From a state-space point of view, the mode is either almost uncontrollable from the input or

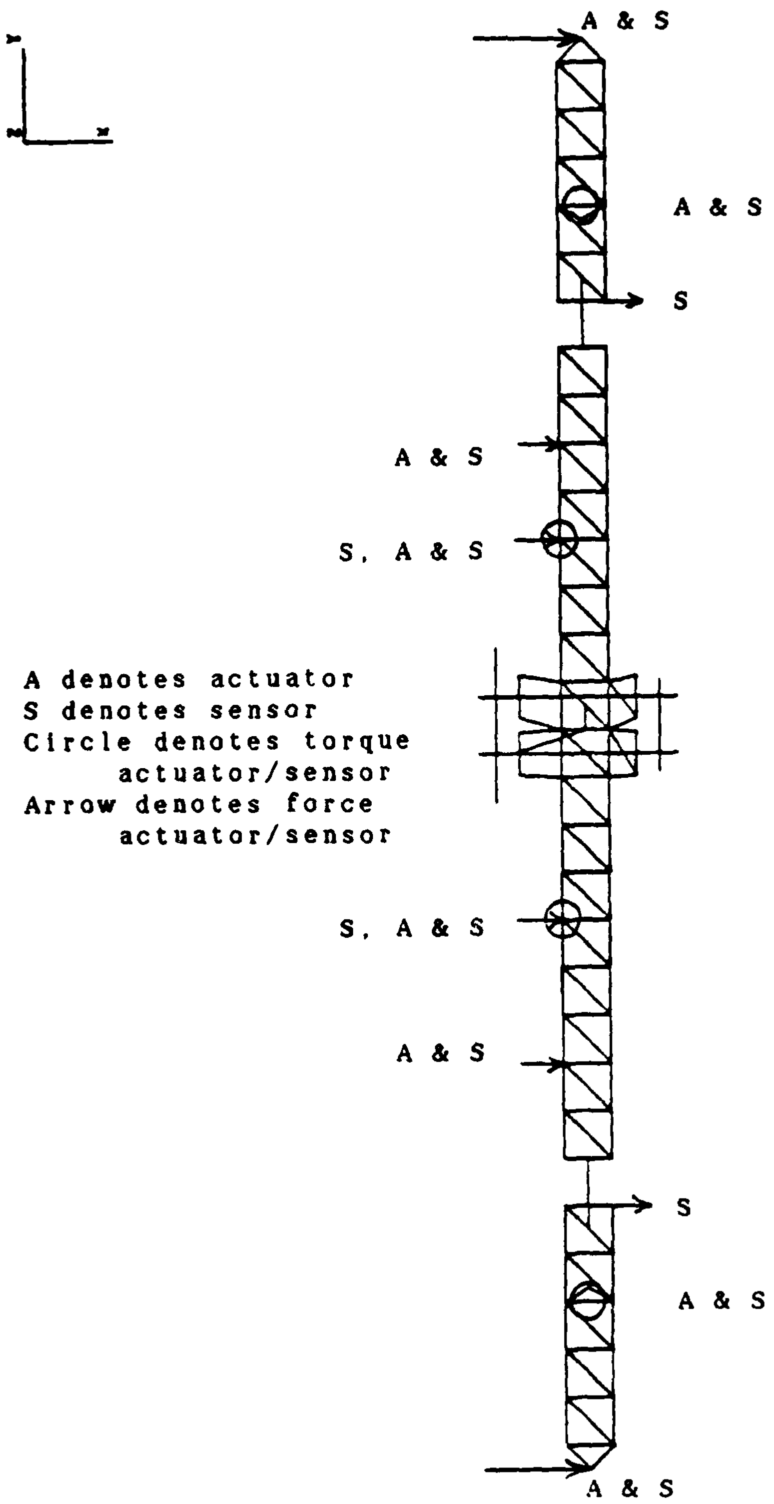


Figure 6a. Actuator/Sensor Locations and Orientations in the X-Direction and about the Z-Axis

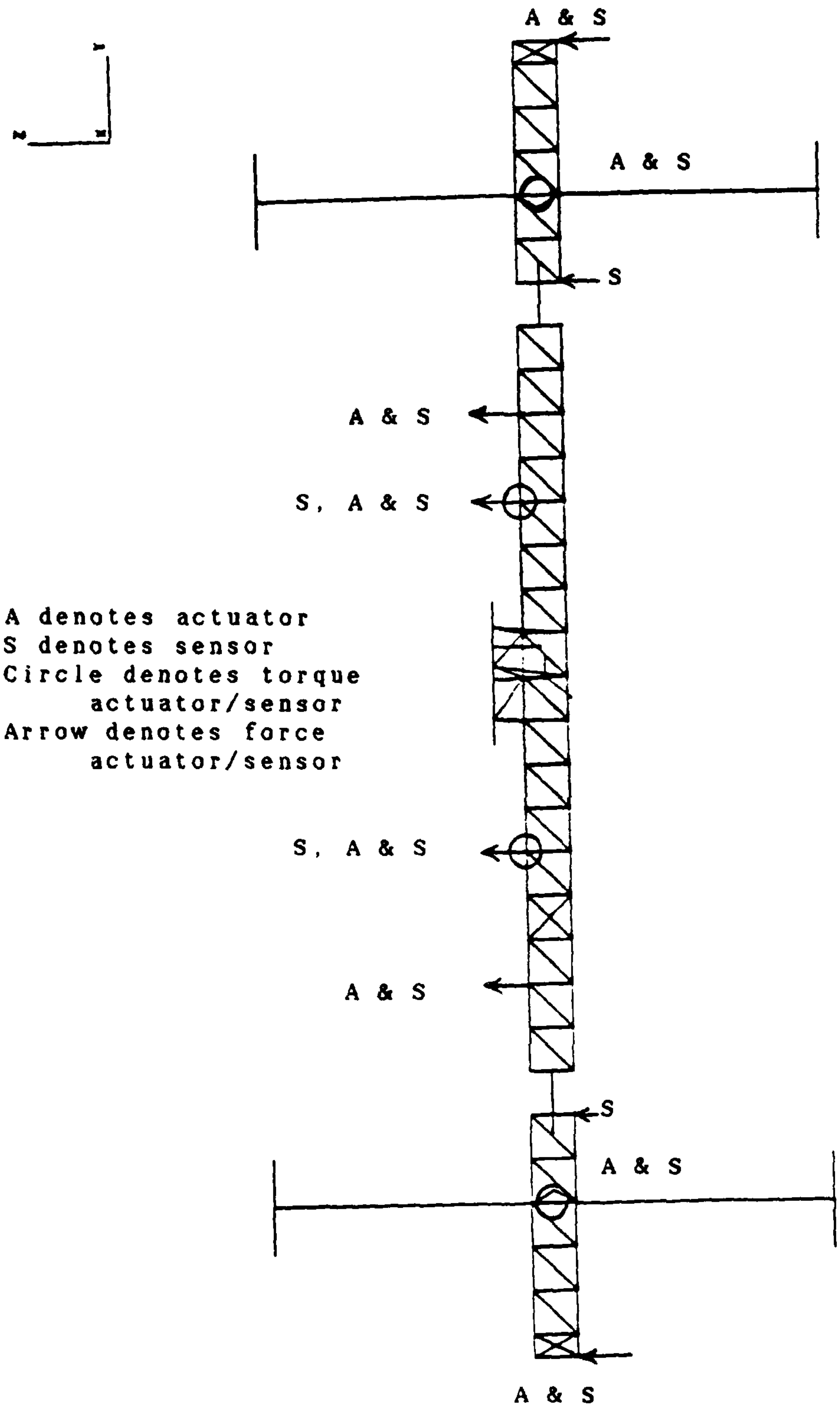


Figure 6b. Actuator/Sensor Locations and Orientations in the Z-Direction and about the X-Axis

unobservable from the output. From this consideration, it is possible to select those modes which contribute most to the transfer function as dominant and keep them in the controlled state, $\bar{z}_c$. Modes that contribute little are modeled in the residual state, $\bar{z}_r$.

The residue of each mode is determined by multiplying the mode's displacement at the actuator location by mode's displacement at the sensor location for each input-output pair. (Ref 14) In terms of previously defined matrices, the residues of the multi-input, multi-output system is computed as follows:

$$R_i = (Cp\xi_i)(\eta_i^T D) \qquad (43)$$

where

Cp = matrix defining the location and orientation of position sensors
ξ_i = ith structural mode shape, column vector of the matrix Φ
η_i^T = row vector of the matrix Φ^T
D = matrix defining the location and orientation of actuators

The residue matrix R_i is an m x l matrix (m outputs, l inputs) (Ref 13), and it can be plotted as a bar chart for each input-output pair as shown in Figure 7. From the modal residues, the following dominancy classification has been derived. For each input-output pair, the modes are ranked from 1 to 30 in descending order of the magnitude of their residues. Then, the rank of each mode is averaged over every input-output pair. Table V shows the dominancy order derived from the modal residue consideration.

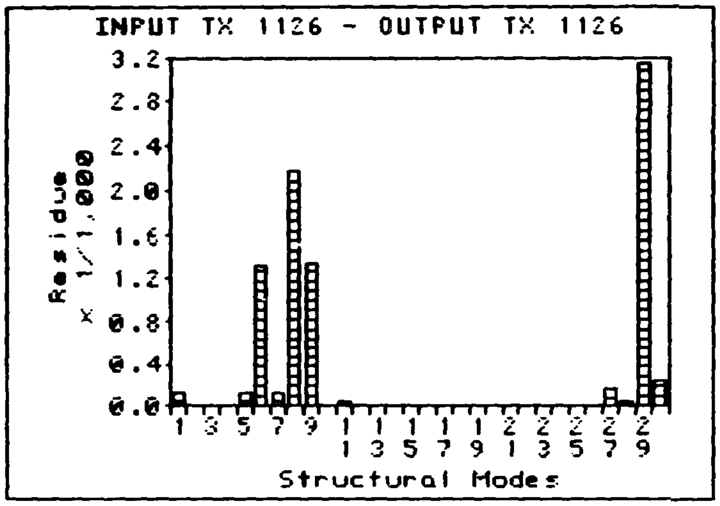


Figure 7a - Residue Bar Chart Example
Collocated Sensor/Actuator

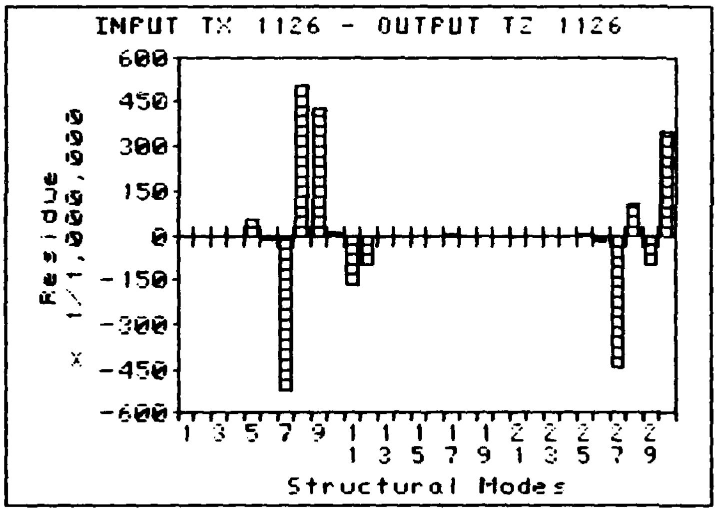


Figure 7b - Residue Bar Chart Example
Non-Collocated Sensor/Actuator

From the dominancy measure of the modal residues, the following modal assignment is made. The three rigid body translational modes are not included in the control system design since they are not controllable by the attitude control system. Each of the three rigid body rotational modes is assigned to a

Rank	Mode Number	Average Rank	Rank	Mode Number	Average Rank
1	27	2.70	16	6	16.43
2	28	4.76	17	22	16.52
3	29	7.60	18	16	17.09
4	12	8.12	19	24	17.40
5	11	9.12	20	20	17.79
6	26	9.16	21	17	18.23
7	30	9.16	22	18	18.83
8	7	9.29	23	19	19.50
9	8	9.50	24	14	21.02
10	9	11.19	25	13	21.29
11	10	11.50	26	5	21.47
12	25	12.62	27	4	22.91
13	23	16.27	28	3	26.42
14	21	16.30	29	1	27.24
15	15	16.30	30	2	29.25

Table V. Dominancy Order Derived by Modal Residue Consideration

separate controller. The remaining twenty-four bending modes are evenly distributed between the three controllers and the residual state vector by considering their average rank. The resulting assignment is:

Controller 1: 6, 7, 8, 9, 10, 11, 12

Controller 2: 5, 25, 26, 27, 28, 29, 30

Controller 3: 4, 15, 16, 21, 22, 23, 24

Residuals: 13, 14, 17, 18, 19, 20

V. Investigation and Results

For an effective control system design, the damping of the controlled modes should be at least doubled and the residual modes should not be adversely affected. With the initial choice of the sixteen collocated actuator/sensor pairs, the resulting eigenvalue analysis is presented in Tables VI and VII. The design eigenvalues show that the control system does not have much control over modes 22 and 24 since their modal dampings are not significantly improved. A characteristic of decoupled control is that the first and last controller will experience a loss of observability and controllability, respectively. (Ref 3) This characteristic can be seen in Table VII where controller damping is lost on modes 15, 16, 21, 22, 23, 24, and 30; and observer damping is lost on modes 7, 8, 9, 10, 11, 12, 25, and 26. The eigenvalues of the residual system (shown in Table VII) indicate that the residual modes are not adversely affected by the controllers.

Since a large number of modes do not have improved observer damping and sensors can be relatively easily attached to the structure, eight sensors are added to the structure. Tables VIII and IX present the eigenvalue analysis for this case. Once again, modes 22 and 24 appear to be uncontrollable. The overall eigenvalue analysis shows that the observer damping of modes 7 through 12 is improved with the additional sensors. The most significant improvement occurred in modes 7, 8, and 9. The vibrational damping is more than doubled in all the modes except seven, and

CONTROLLER SYSTEM 1		
MODE	FREQUENCY	DAMPING
6	0.5096	0.7516
7	1.2384	0.1515
8	1.2772	0.1408
9	2.6263	0.0423
10	2.9054	0.0213
11	3.0929	0.0347
12	3.4874	0.0360

CONTROLLER SYSTEM 2		
MODE	FREQUENCY	DAMPING
5	0.2728	0.7201
25	4.6274	0.0116
26	4.6401	0.0122
27	4.7569	0.0280
28	4.9332	0.0308
29	5.3648	0.0284
30	6.1424	0.0137

CONTROLLER SYSTEM 3		
MODE	FREQUENCY	DAMPING
4	0.5138	0.7523
15	4.2851	0.0092
16	4.3081	0.0089
21	4.4071	0.0145
22	4.4152	0.0061
23	4.4308	0.0147
24	4.4727	0.0065

OBSERVER SYSTEM 1		
MODE	FREQUENCY	DAMPING
6	0.5096	0.7516
7	1.2384	0.1515
8	1.2772	0.1408
9	2.6263	0.0423
10	2.9054	0.0213
11	3.0929	0.0347
12	3.4874	0.0360

OBSERVER SYSTEM 2		
MODE	FREQUENCY	DAMPING
5	0.2728	0.7201
25	4.6274	0.0116
26	4.6401	0.0122
27	4.7569	0.0280
28	4.9332	0.0308
29	5.3648	0.0284
30	6.1424	0.0137

OBSERVER SYSTEM 3		
MODE	FREQUENCY	DAMPING
4	0.5138	0.7523
15	4.2851	0.0092
16	4.3081	0.0089
21	4.4071	0.0146
22	4.4152	0.0061
23	4.4308	0.0147
24	4.4727	0.0065

Table VI. Design Eigenvalues with Sixteen Collocated Actuator/Sensor Pairs

CONTROLLER SYSTEM 1		
MODE	FREQUENCY	DAMPING
6	0.5096	0.7516
7	1.2384	0.1515
8	1.2772	0.1408
9	2.6263	0.0423
10	2.9054	0.0213
11	3.0929	0.0347
12	3.4874	0.0360

OBSERVER SYSTEM 1		
MODE	FREQUENCY	DAMPING
6	0.0506	0.7076
7	1.2270	0.0052
8	1.2676	0.0050
9	2.6254	0.0050
10	2.9046	0.0050
11	3.0932	0.0050
12	3.4876	0.0050

CONTROLLER SYSTEM 2		
MODE	FREQUENCY	DAMPING
5	0.0815	0.7083
25	4.6271	0.0115
26	4.6394	0.0118
27	4.7588	0.0130
28	4.9320	0.0110
29	5.3646	0.0100
30	6.1424	0.0050

OBSERVER SYSTEM 2		
MODE	FREQUENCY	DAMPING
5	0.2539	0.7184
25	4.6271	0.0051
26	4.6393	0.0052
27	4.7583	0.0174
28	4.9325	0.0086
29	5.3648	0.0274
30	6.1423	0.0095

CONTROLLER SYSTEM 3		
MODE	FREQUENCY	DAMPING
4	0.0752	0.7081
15	4.2836	0.0051
16	4.3068	0.0053
21	4.4087	0.0054
22	4.4152	0.0050
23	4.4319	0.0058
24	4.4727	0.0050

OBSERVER SYSTEM 3		
MODE	FREQUENCY	DAMPING
4	0.5138	0.7523
15	4.2851	0.0092
16	4.3081	0.0089
21	4.4071	0.0146
22	4.4152	0.0061
23	4.4308	0.0147
24	4.4727	0.0065

RESIDUAL SYSTEM		
MODE	FREQUENCY	DAMPING
13	4.0991	0.0050
14	4.1242	0.0050
17	4.3137	0.0050
18	4.3363	0.0050
19	4.3700	0.0050
20	4.3918	0.0050

Table VII. Overall Eigenvalue Analysis with Sixteen Collocated Actuator/Sensor Pairs

CONTROLLER SYSTEM 1			OBSERVER SYSTEM 1		
MODE	FREQUENCY	DAMPING	MODE	FREQUENCY	DAMPING
6	0.5096	0.7516	6	0.5541	0.7594
7	1.2384	0.1515	7	1.2403	0.1629
8	1.2772	0.1408	8	1.2786	0.1511
9	2.6263	0.0423	9	2.6264	0.0446
10	2.9054	0.0213	10	2.9057	0.0231
11	3.0929	0.0347	11	3.0928	0.0373
12	3.4874	0.0360	12	3.4873	0.0392

CONTROLLER SYSTEM 2			OBSERVER SYSTEM 2		
MODE	FREQUENCY	DAMPING	MODE	FREQUENCY	DAMPING
5	0.2728	0.7201	5	0.3004	0.7229
25	4.6274	0.0116	25	4.6275	0.0117
26	4.6401	0.0122	26	4.6404	0.0123
27	4.7569	0.0280	27	4.7565	0.0326
28	4.9331	0.0308	28	4.9333	0.0345
29	5.3648	0.0284	29	5.3649	0.0324
30	6.1424	0.0137	30	6.1424	0.0172

CONTROLLER SYSTEM 3			OBSERVER SYSTEM 3		
MODE	FREQUENCY	DAMPING	MODE	FREQUENCY	DAMPING
4	0.5138	0.7523	4	0.5586	0.7603
15	4.2851	0.0092	15	4.2851	0.0093
16	4.3081	0.0089	16	4.3082	0.0089
21	4.4071	0.0146	21	4.4071	0.0146
22	4.4152	0.0061	22	4.4152	0.0061
23	4.4308	0.0147	23	4.4308	0.0147
24	4.4727	0.0065	24	4.4727	0.0066

Table VIII. Design Eigenvalues with Sixteen Collocated Actuator/Sensor Pairs and Eight Additional Sensors

CONTROLLER SYSTEM 1		
MODE	FREQUENCY	DAMPING
6	0.5096	0.7516
7	1.2384	0.1515
8	1.2772	0.1408
9	2.6263	0.0423
10	2.9054	0.0213
11	3.0929	0.0347
12	3.4874	0.0360

OBSERVER SYSTEM 1		
MODE	FREQUENCY	DAMPING
6	0.4868	0.7477
7	1.2292	0.0481
8	1.2666	0.0233
9	2.6254	0.0119
10	2.9046	0.0065
11	3.0932	0.0073
12	3.4876	0.0058

CONTROLLER SYSTEM 2		
MODE	FREQUENCY	DAMPING
5	0.0815	0.7083
25	4.6271	0.0115
26	4.6394	0.0118
27	4.7588	0.0130
28	4.9320	0.0110
29	5.3646	0.0100
30	6.1424	0.0050

OBSERVER SYSTEM 2		
MODE	FREQUENCY	DAMPING
5	0.2962	0.7225
25	4.6271	0.0051
26	4.6393	0.0052
27	4.7589	0.0212
28	4.9319	0.0105
29	5.3648	0.0313
30	6.1423	0.0133

CONTROLLER SYSTEM 3		
MODE	FREQUENCY	DAMPING
4	0.0752	0.7081
15	4.2836	0.0051
16	4.3068	0.0053
21	4.4087	0.0054
22	4.4152	0.0050
23	4.4319	0.0058
24	4.4727	0.0050

OBSERVER SYSTEM 3		
MODE	FREQUENCY	DAMPING
4	0.5586	0.7603
15	4.2851	0.0093
16	4.3082	0.0089
21	4.4071	0.0146
22	4.4152	0.0061
23	4.4308	0.0147
24	4.4727	0.0066

RESIDUAL SYSTEM		
MODE	FREQUENCY	DAMPING
13	4.0991	0.0050
14	4.1242	0.0050
17	4.3137	0.0050
18	4.3363	0.0050
19	4.3700	0.0050
20	4.3918	0.0050

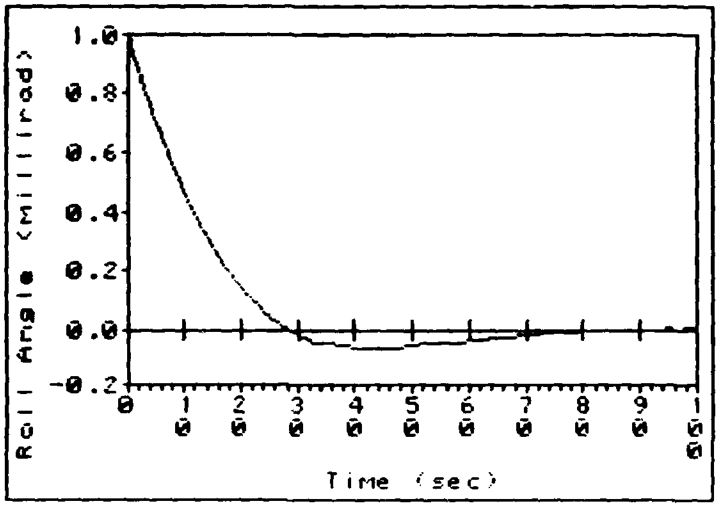
Table IX. Overall Eigenvalue Analysis with Sixteen Collocated Actuator/Sensor Pairs and Eight Additional Sensors

all the modes except three have at least a twenty percent increase in damping. Also, the residual modes are not destabilized.

The attitude control system must be able to stabilize the space station's attitude and reject disturbances on the structure. Therefore, its performance is analyzed by the system's response to initial attitude displacements and rates and two disturbances - crew motion and shuttle docking. For a system that can be described by the equation $\dot{\bar{z}} = A\bar{z}$, its response to initial conditions is given by $\bar{z}(t) = e^{At}\,\bar{z}(0)$. The matrix exponential, e^{At}, is computed for a time increment of one second using the eigenvectors and eigenvalues of matrix A. (Ref 8) The forces due to crew motion and shuttle docking are modeled as impulses. An impulse consisting of a large force acting for a very short time has the effect of giving the structure an initial velocity while leaving its initial displacement zero. (Ref 11) The initial velocity of the physical coordinates is given by $\dot{\bar{x}}(0) = [M]^{-1}I$ where [M] is the mass matrix and I is a vector that contains the magnitude of the impulse at the appropriate physical coordinate. Since $\bar{\eta} = \Phi^{-1}\bar{x}$ and $\Phi^{-1} = \Phi^{T}M$, the initial velocity in modal coordinates is $\dot{\bar{\eta}}(0) = \Phi^{T}I$. The attitude response of the system to these initial conditions is shown in the following paragraphs. Also, as a single measure of the system's performance, the variation of the structure's total energy with time is shown.

Response to Initial Angle and Rate

The control system must be able to bring initial conditions of attitude position and rate to zero in a reasonable amount of time. This performance will be necessary following transition



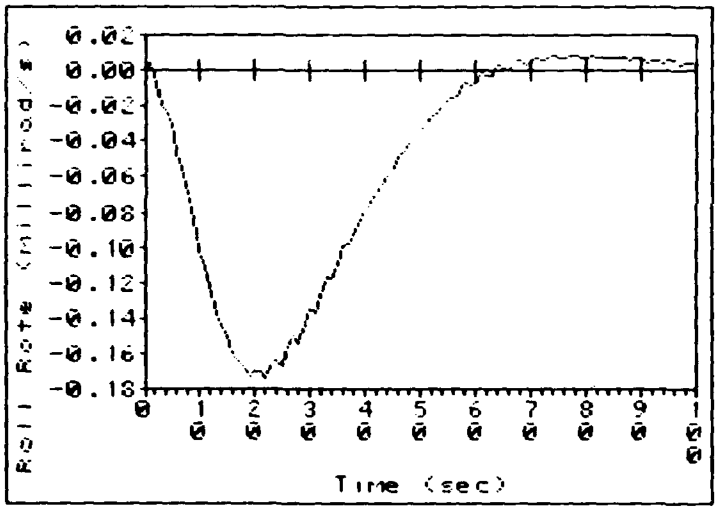
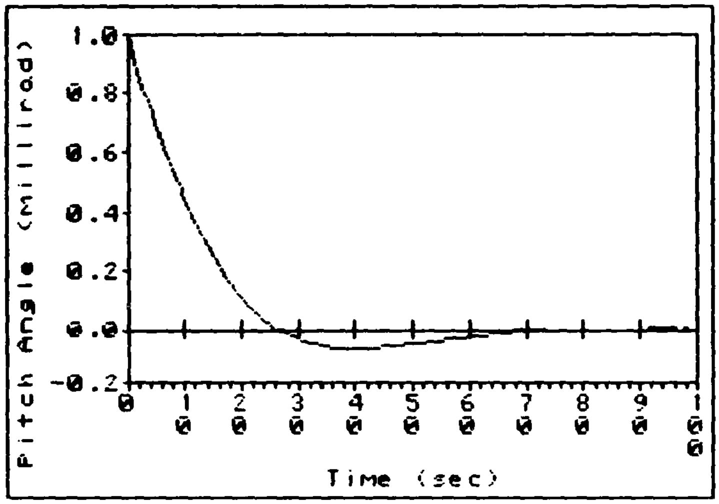


Figure 8. Roll Attitude Initial Angle Response

from reboost and docking maneuvers. Figures 8 through 10 show attitude and rate responses to 0.001 radian initial attitudes. These results show that the control system will stabilize the roll and pitch axes in about 100 seconds with the yaw axis stabilizing within 20 seconds. The energy variations for the three initial



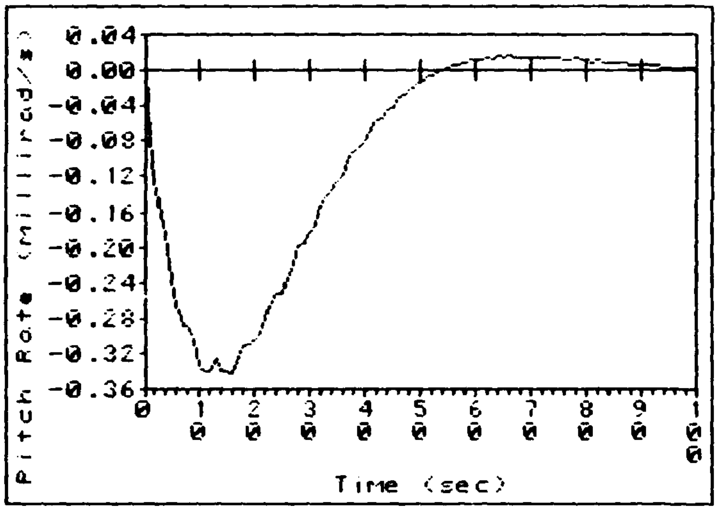


Figure 9. Pitch Attitude Initial Angle Response

attitudes are shown in Figure 11. Figures 12 through 14 show similar results for the attitude and rate responses to initial rates of 0.0001 rad/s. The energy variations are shown in Figure 15. The transient responses are primarily due to the rigid body modes. These responses are comparable to the responses of a

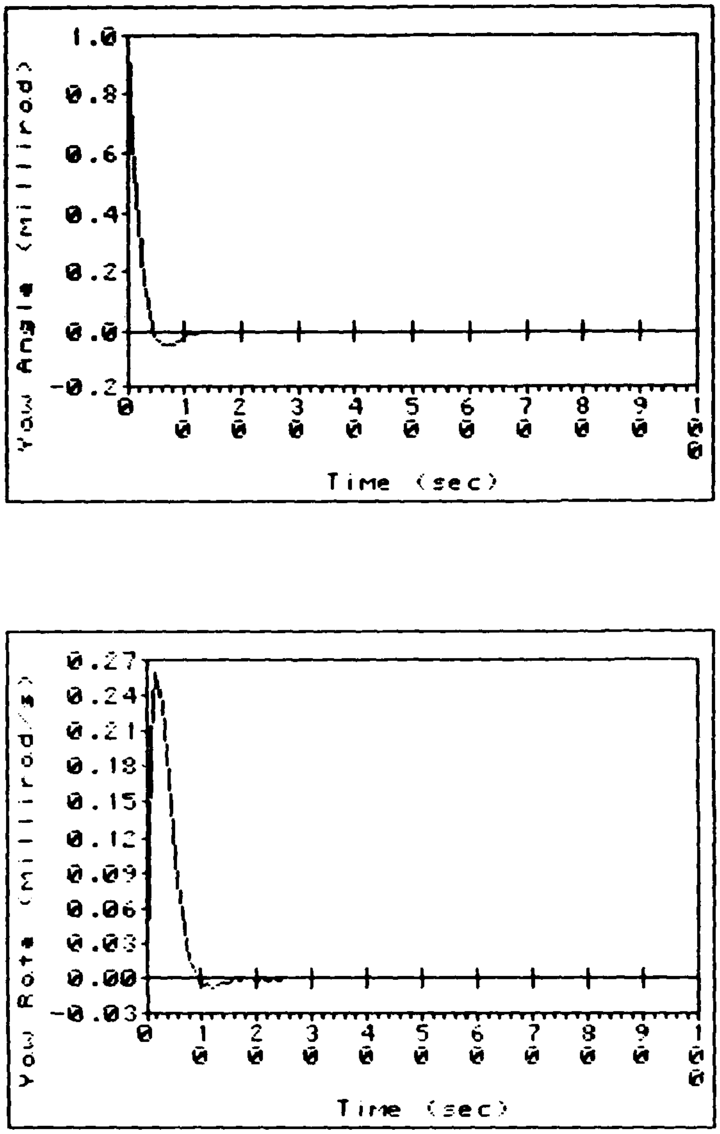


Figure 10. Yaw Attitude Initial Angle Response

normal mode controller designed by the Space Systems Division of the Ford Aerospace Corporation. The responses of the normal mode controller are shown in Figures 16 and 17. These simulation results verify that the control system will stabilize the attitude in about 100 seconds, a time consistent with the bandwidth of the control system. (Ref 4)

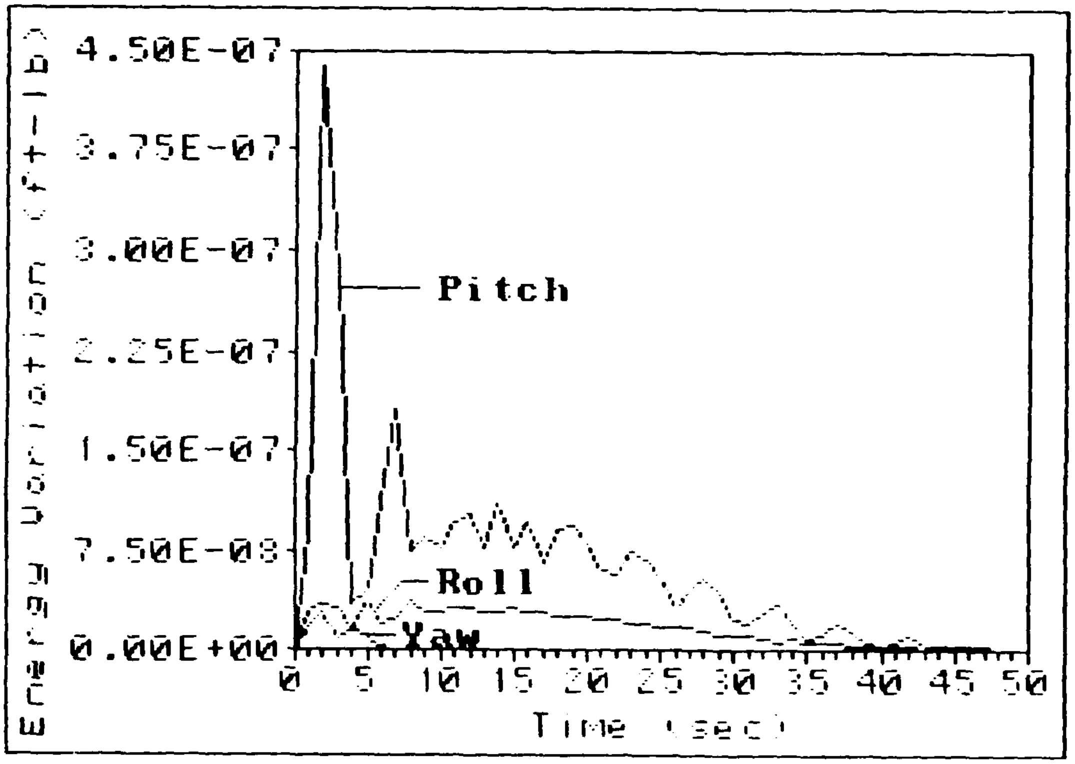
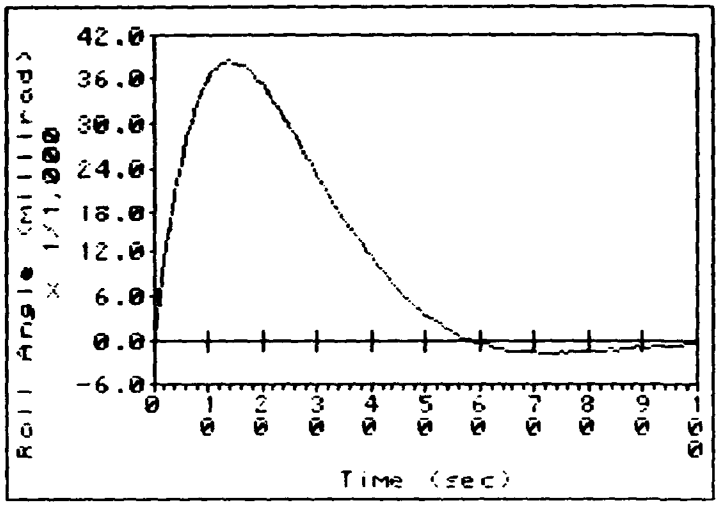


Figure 11. Energy Variations to Initial Attitude Angle



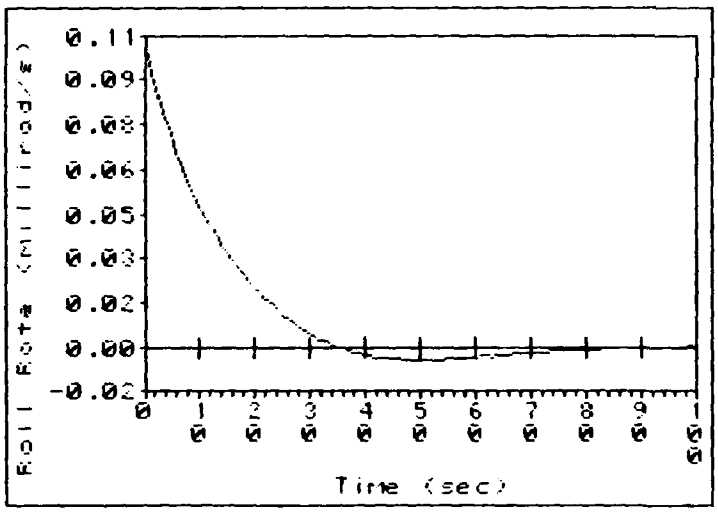


Figure 12. Roll Attitude Initial Rate Response

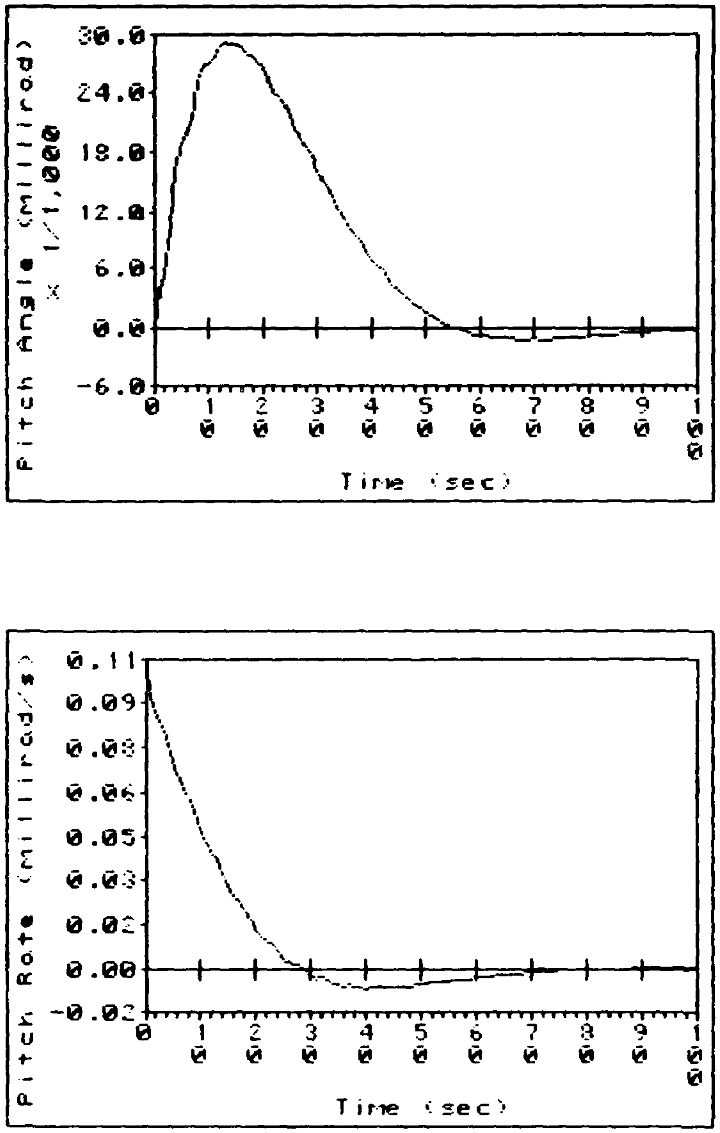


Figure 13. Pitch Attitude Initial Rate Response

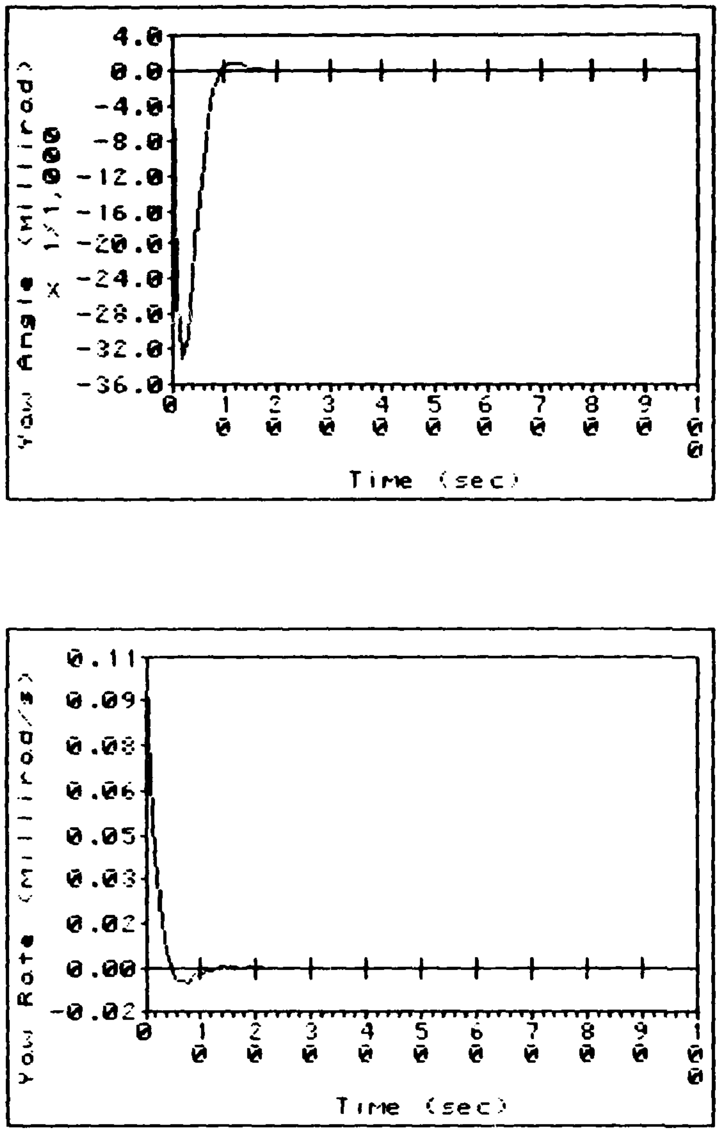


Figure 14. Yaw Attitude Initial Rate Response

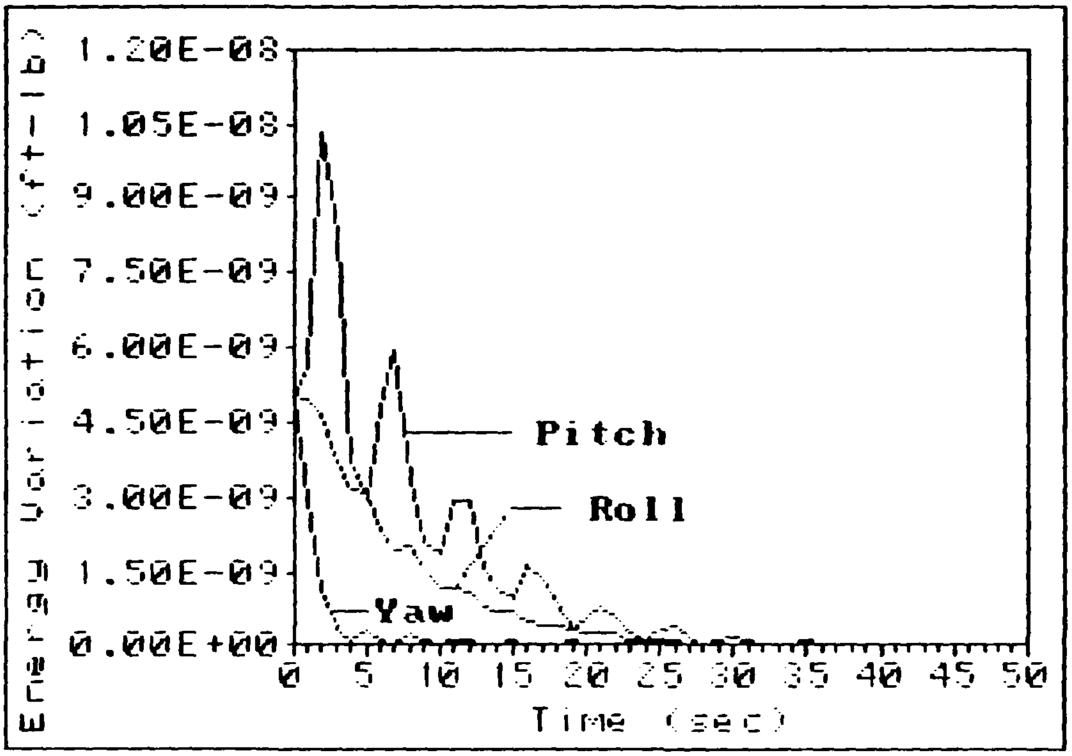


Figure 15. Energy Variations to Initial Attitude Rate

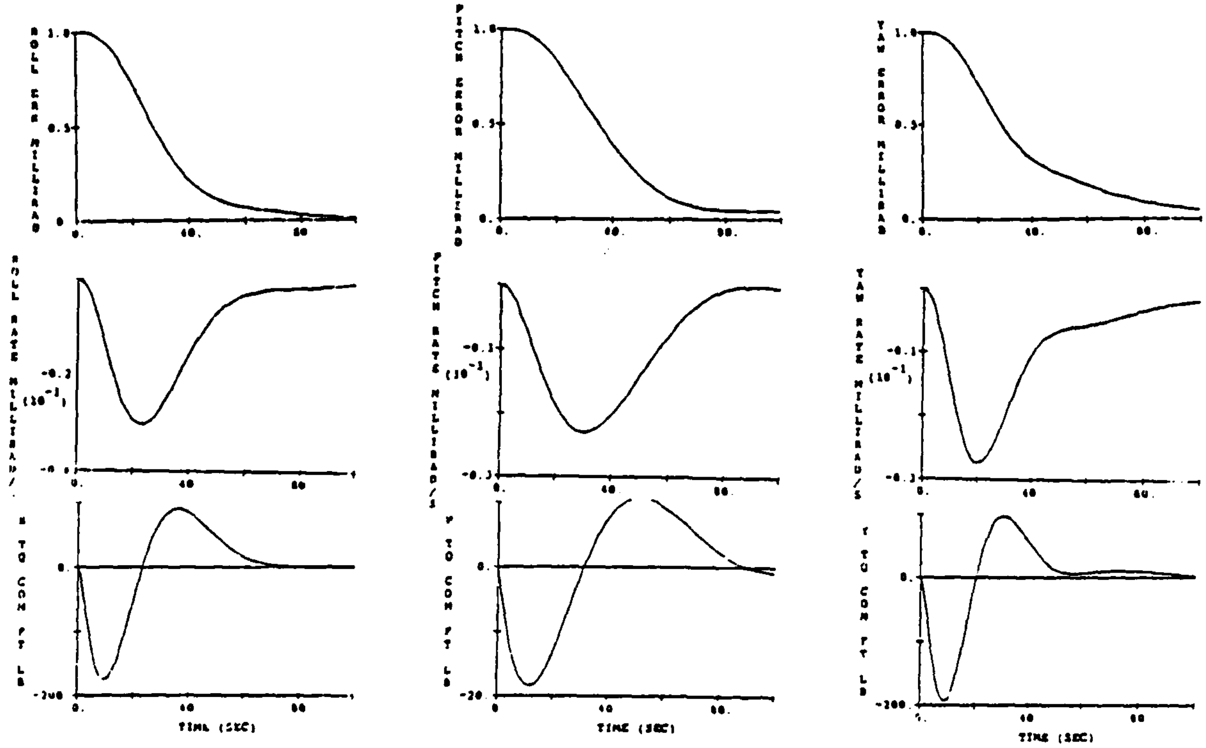


Figure 16. Normal Mode Initial Angle Response

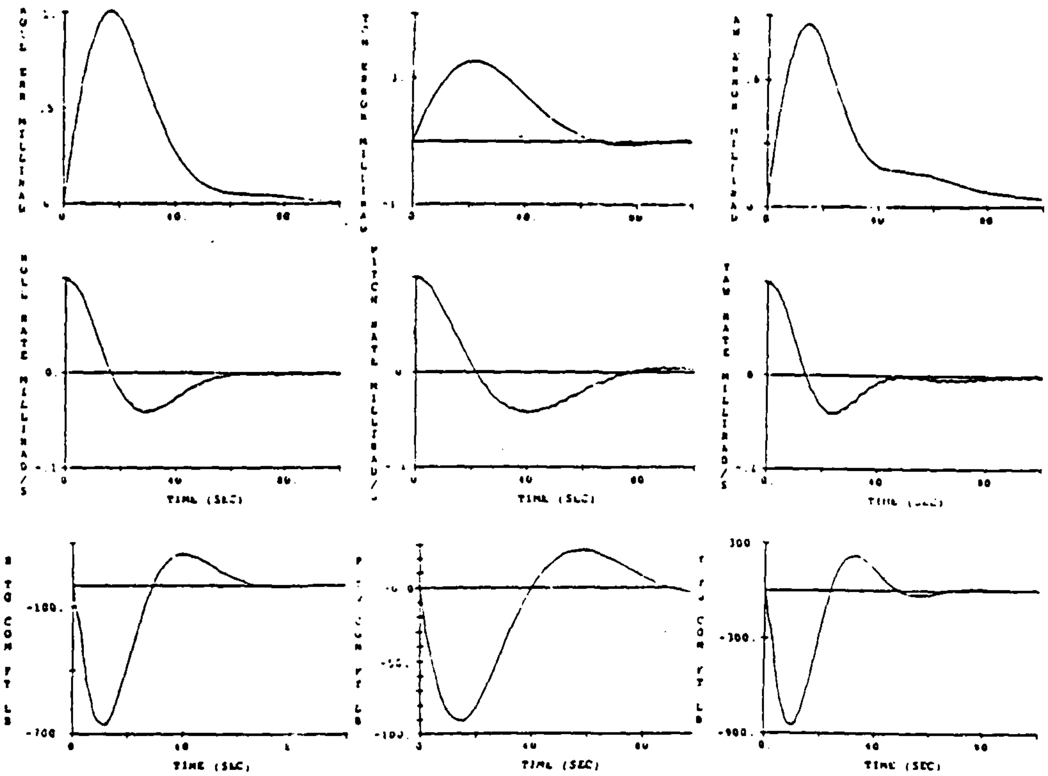


Figure 17. Normal Mode Initial Rate Response

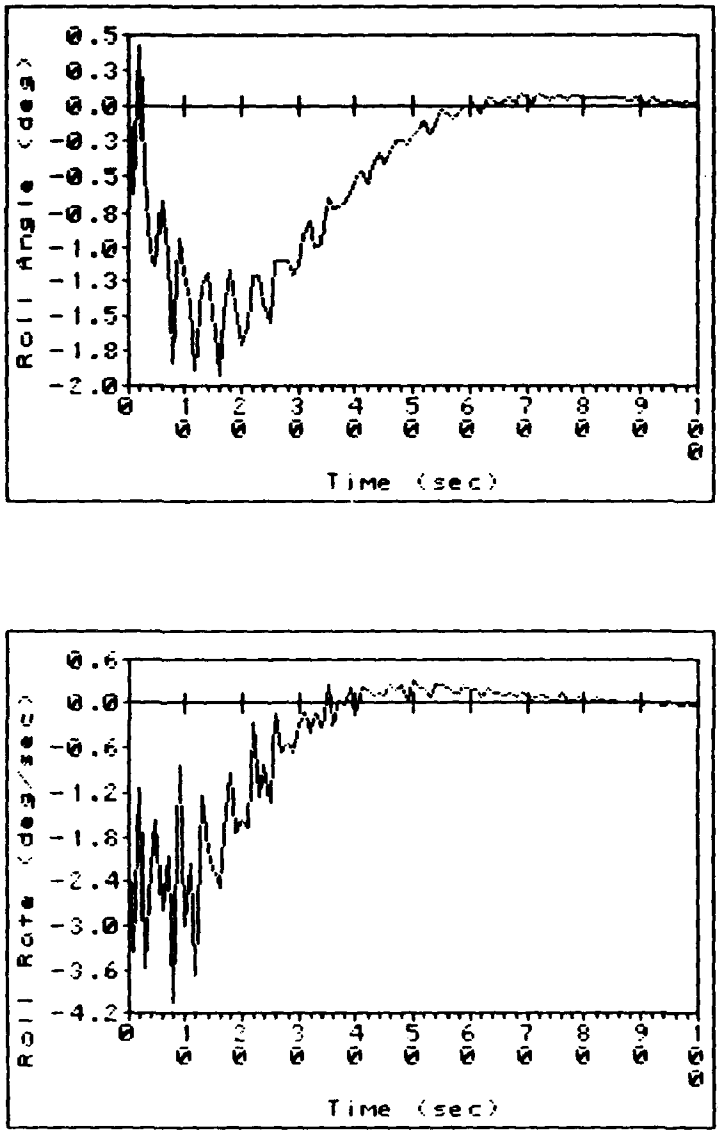
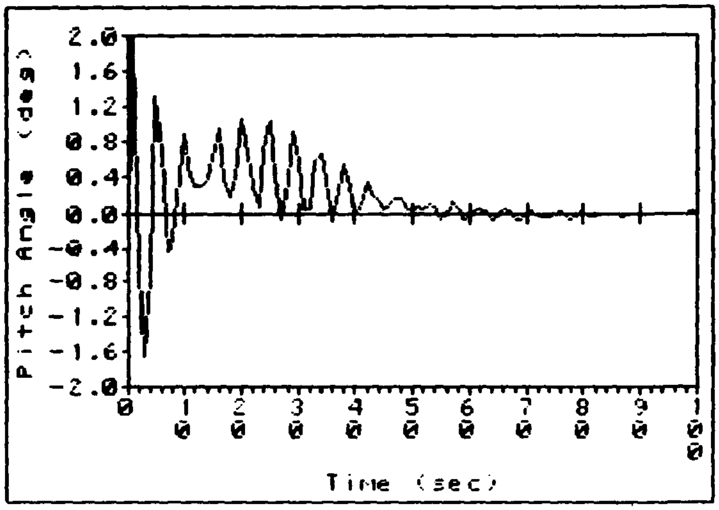


Figure 18. *Roll Attitude Response to Crew Disturbance Impulse*

Response to Crew Disturbance

Common impulsive disturbances result from gross crew motion. Of primary interest are the peak angular displacements resulting from these disturbances. (Ref 4) The largest disturbance due to



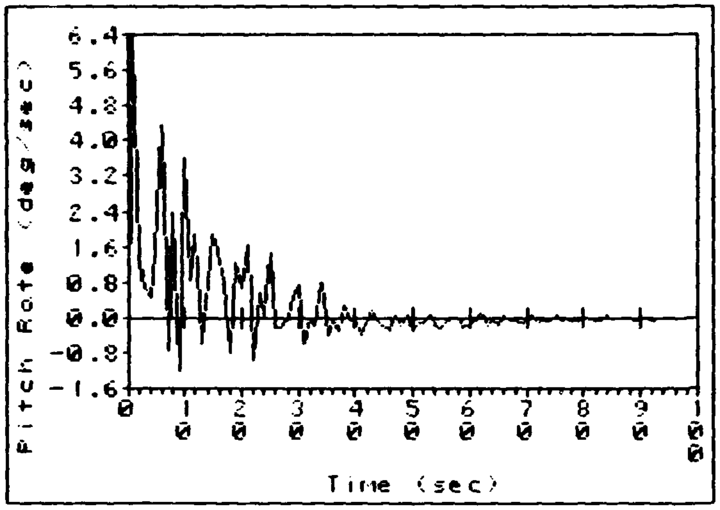
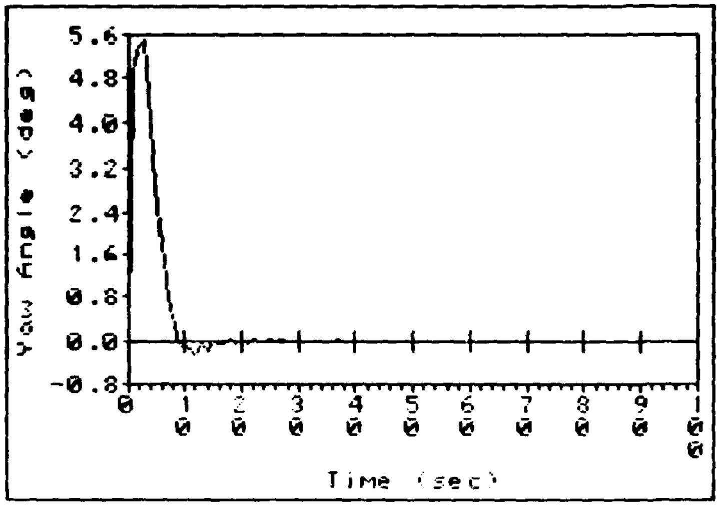


Figure 19. Pitch Attitude Response to Crew Disturbance Impulse

crew motion is an astronaut with a mass of 153 lbm pushing forcefully off a wall, reaching a speed of 7.09 ft/sec, and stopping at the opposite wall. (Ref 12) This disturbance represents a 33.7 lb_f-sec impulse. Figures 18 through 20 show the



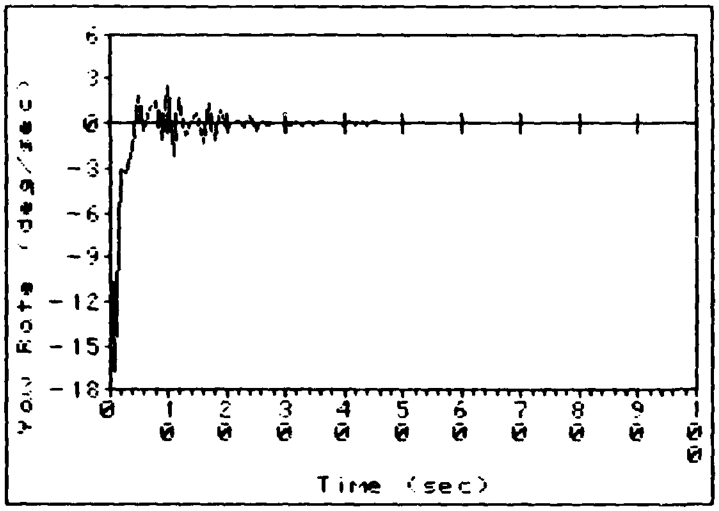


Figure 20. Yaw Attitude Response to
Crew Disturbance Impulse

attitude responses to an impulse of 33.7 lb_f-sec applied at the end of a module (node location #13011) in the +y-direction. Such a force impulse generates maximum angular displacements of 1.93°, 1.97°, and 5.50° about the roll, pitch, and yaw axes, respectively. (Ref 4) Once again, these responses are comparable

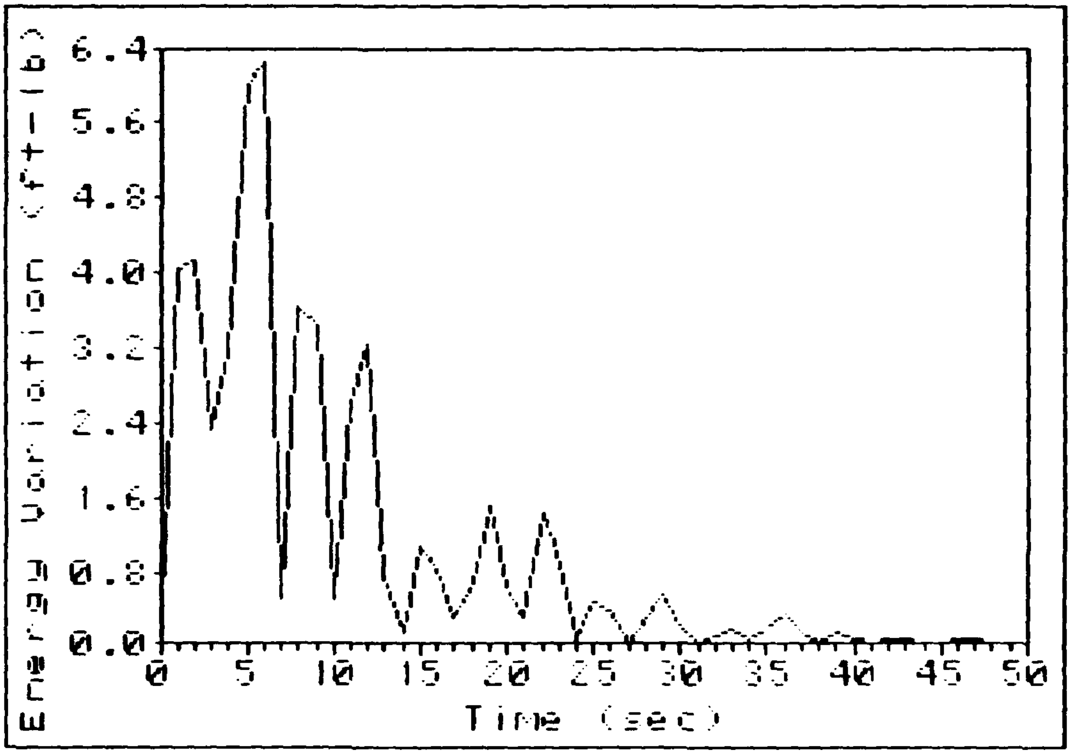


Figure 21. Energy Variation to Crew Disturbance Impulse

to the responses of the normal mode controller shown in Figure 26. The energy variation due to this impulse, shown in Figure 21, is a good illustration of the control system's ability to reject crew disturbances. The rigid body modes still dominate the transients.

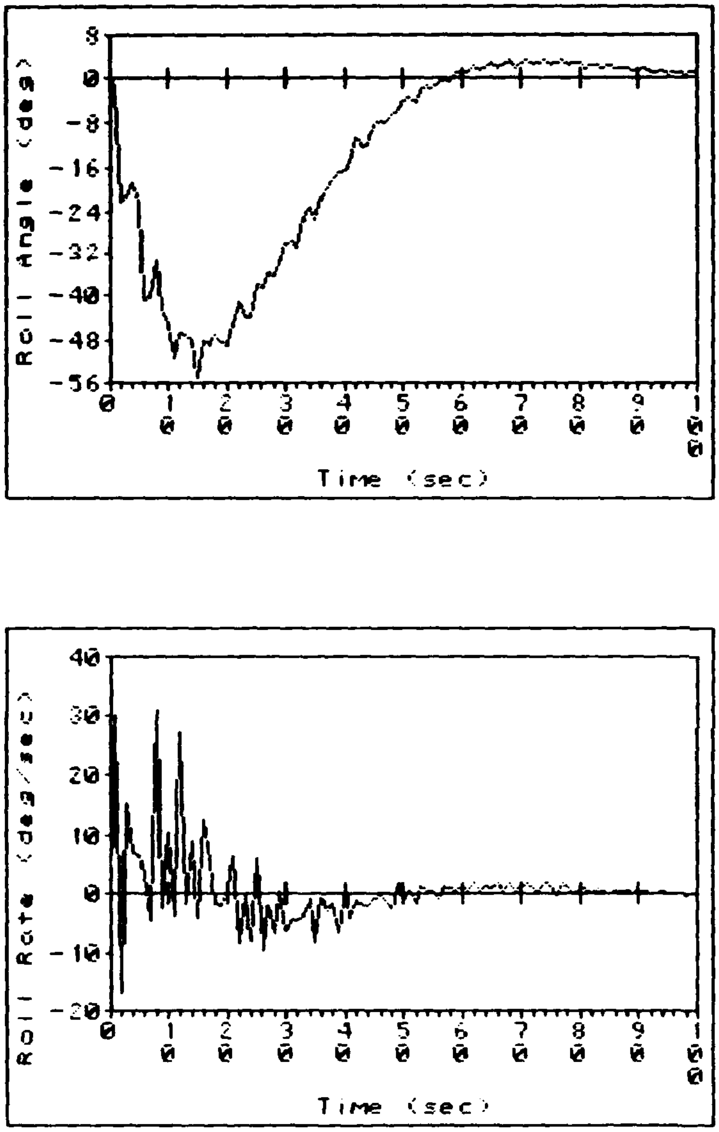
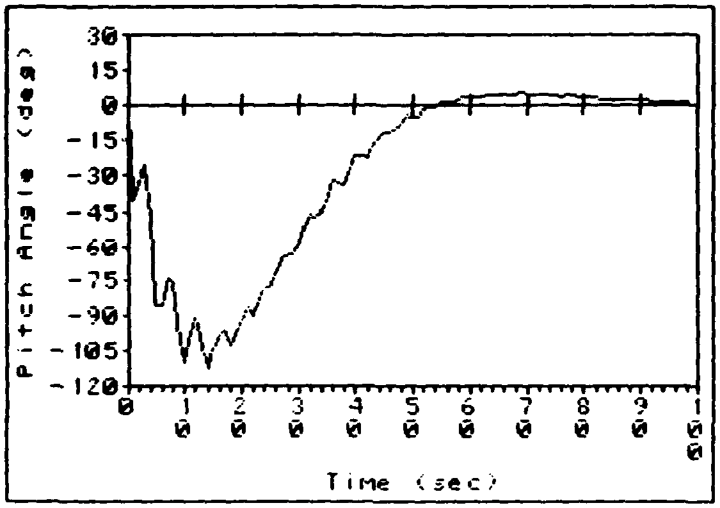


Figure 22. Roll Attitude Response to Shuttle Docking Impulse

Response to Shuttle Docking

The space station will experience impacts from the docking or berthing of vehicles such as the Shuttle and Orbital Maneuvering Vehicles. The largest impulse can be modeled as a hard-docking by



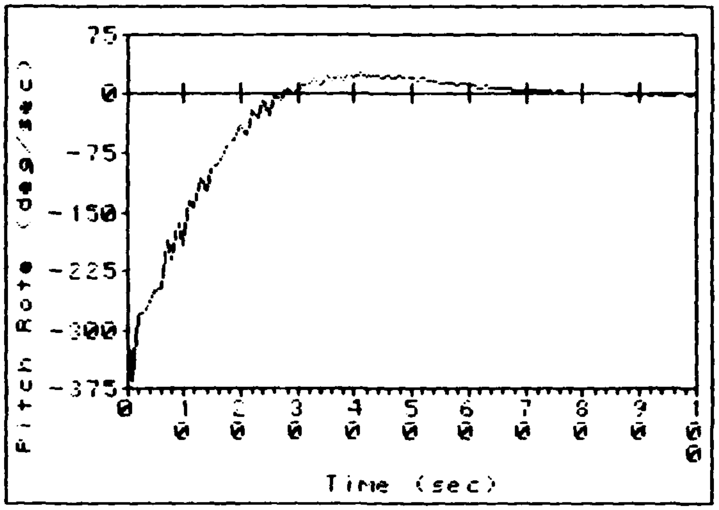
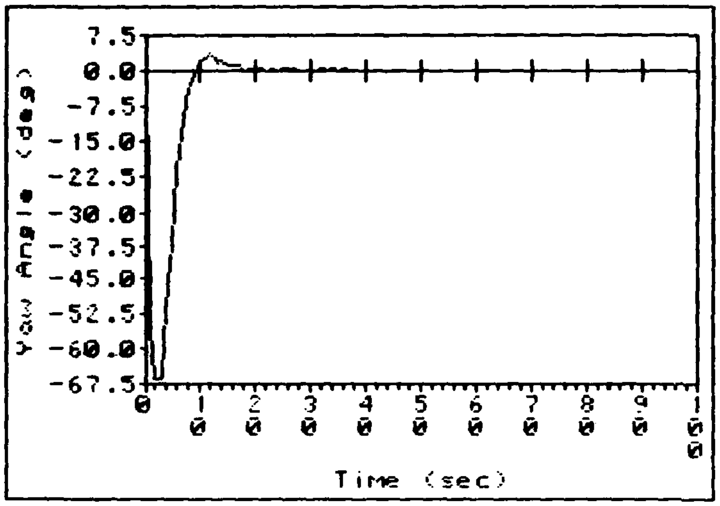


Figure 23. Pitch Attitude Response to Shuttle Docking Impulse

a fully loaded Shuttle with a mass of 242,500 lbm and a 0.2 ft/sec closing speed toward the -x direction. (Ref 13) This docking maneuver causes an impulse of 1516 lb_f-sec on the structure. The docking port is at NASTRAN node location #13051, on the +x side of the module area (see Figure 1). (Ref 4) Figures 22, 23, and 24



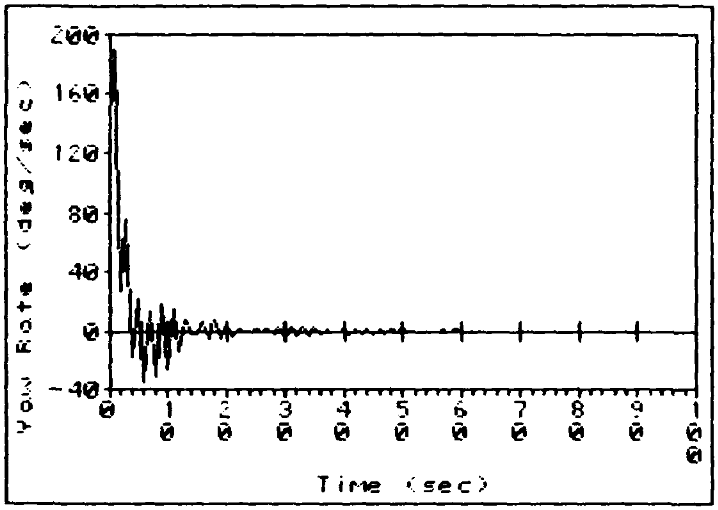


Figure 24. Yaw Attitude Response to Shuttle Docking Impulse

show the attitude responses to the impulse from Shuttle hard-docking, and the energy variation is shown in Figure 25. This impulse generates large angular displacements that would exceed the system's performance requirements. The net momentum that must be absorbed is about 13,000 ft-lb-s on both pitch and

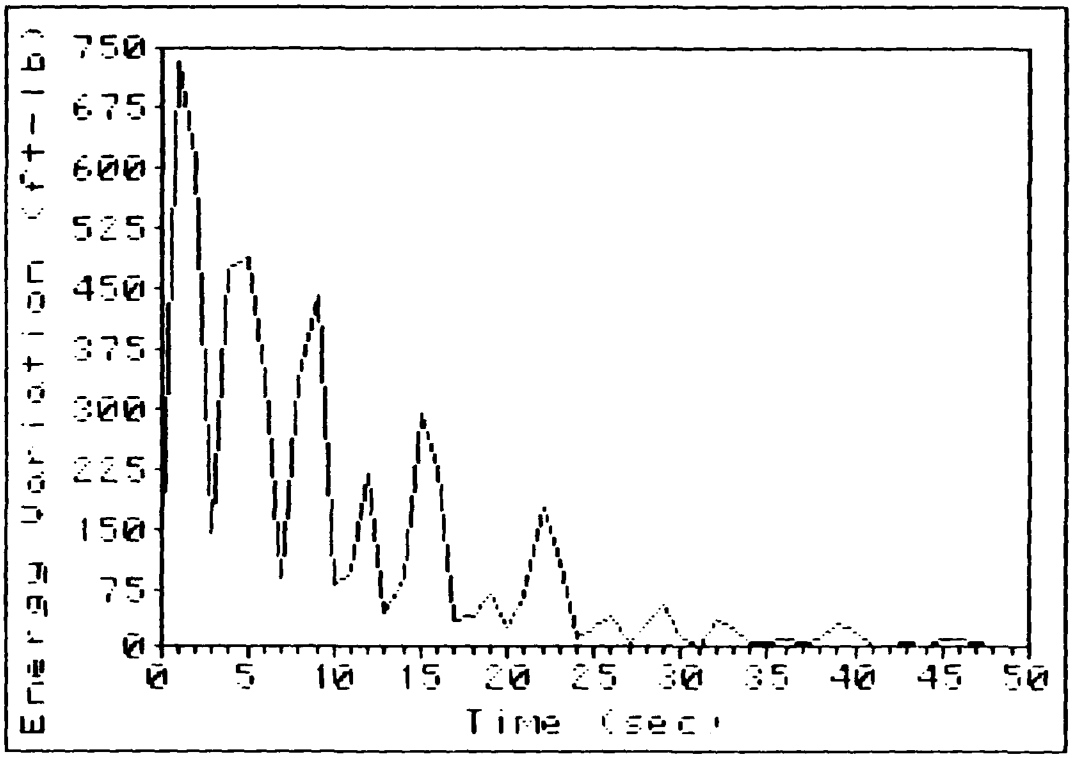


Figure 25. Energy Variation to Shuttle Docking Impulse

yaw axes. These results indicate that this control system alone is not adequate for Shuttle hard-docking which agrees with the results of the normal mode controller shown in Figure 27. (Ref 4)

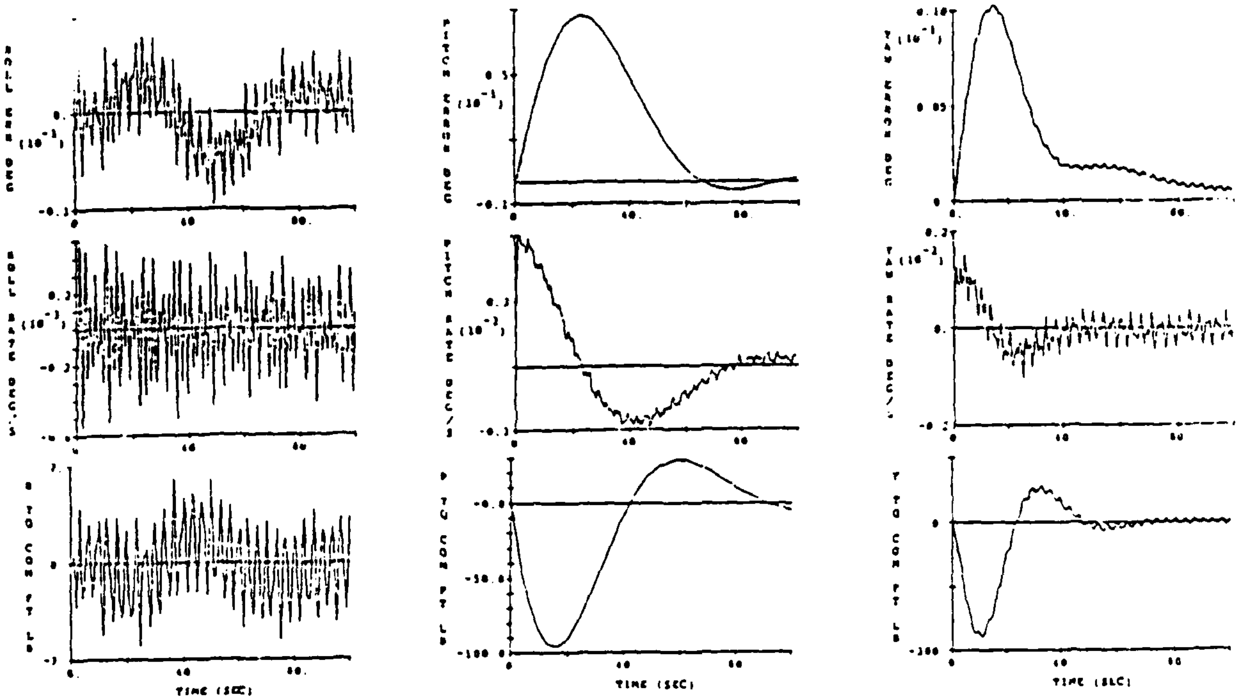


Figure 26. Normal Mode Crew Disturbance Impulse Response

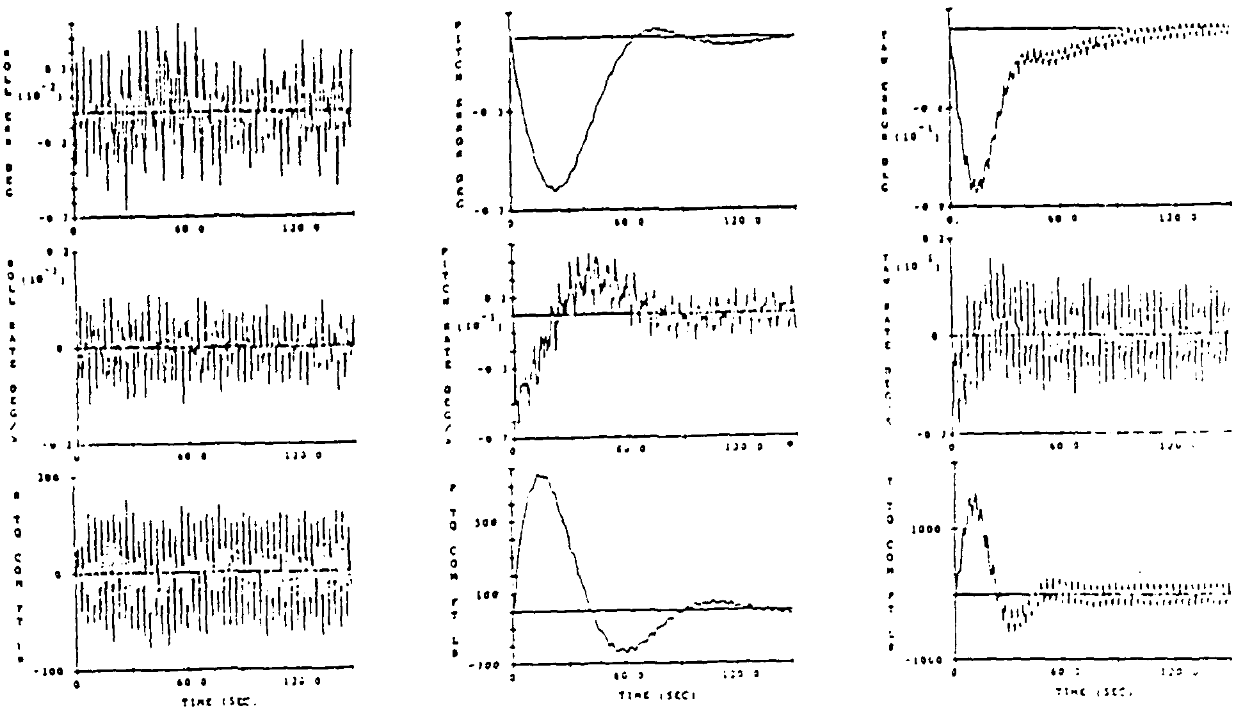


Figure 27. Normal CMG Mode Response to Shuttle Docking Impulse

VI. Conclusions and Recommendations

The space station is characterized by requirements for evolutionary and modular growth presenting new challenges in distributive control that utilizes multi-state active control. (Ref 6) Because of these requirements, active control utilizing a decoupled control technique is applied to a control system design for a space station. The study emphasized basic concepts and methodology for decoupled controller design. The decoupled controller design for flexible structures with noncollocated actuators and sensors was accomplished using linear optimal regulator theory. The Phase 1 CETF Space Station model proved to be a challenging reference plant for the investigation of order reduction and controller design. The order reduction approach which retains modes with high modal residues resulted in a satisfactory reduced model. Its application is straight forward and integrated into the process of generating state space forms out of the modal data from the finite element model. The decoupled control concept for vibration damping and attitude control proved to be appropriate. For the model, it was possible to design a control system that stabilized the attitude and rejected crew disturbances. In general, the increase in modal damping eases the attitude controller design, reduces the sensitivity to model uncertainties, and smooths the system response and controller action. (Ref 14)

This investigation demonstrated the feasibility of using multiple decoupled controllers to maintain system stability. The

control system was able to increase the modal damping by a factor of two for a majority of the modes. Significant increases were also obtained for the other modes while the residual modes were not affected by the controllers. Total controller decoupling was achieved while maintaining controllers and system stability for the model. These results indicate that the proposed active modal control is a feasible process capable of satisfying the requirements indicated for large space structures.

The inability to affect modes 22 and 24 can be attributed to two possible reasons. First, the sensor and actuator placement may not be suitable for controlling these modes. The repositioning of available actuators/sensors or the addition of actuators/sensors may resolve this problem. Second, the modal assignment to each controller can have a major impact on the system stability achieved. This impact is evident in the loss of observability and controllability of the first and last controllers, respectively. Therefore, the modal assignment could be examined again to find a more compatible grouping of modes. Since actuator/sensor locations and modal assignments greatly affect the control system performance, studies in these two areas could improve the observability and controllability of the existing system.

Another way to improve the vibrational damping of the structure would be to select different weighting matrices to produce acceptable closed-loop eigenvalues. A procedure for choosing and forming both state and control frequency weighting matrices is shown in reference 2. A different method for model

order reduction could improve the model of the structure for control system design. Several studies and methods are available to determine which modes would best model the structure for a reduced order controller. For this space station model, frequency truncation proved effective since a large frequency separation existed between modes 30 and 31. However, modal cost analysis could provide a more effective reduced order model than simple frequency truncation.

Since the space station is characterized with changing structural rigid body and flexible modes, a control system must be robust. Numerous publications discuss the theory of robustness of multivariable feedback systems. (Ref 2) For example, reference 3 considers the effects of structural perturbations on a decoupled control system applied to the CSDL I model. Therefore, evaluation of the stability and performance robustness of the control system design would be help to determine the feasibility of this system.

The initial objective of this thesis was to determine the dynamic effects on space station stability and micro G environment of crew translation on a space station structure. To facilitate translation along the space station structure, a carrier system will be provided that accommodates one or two astronauts and equipment. The Structures and Mechanics Division at NASA's Johnson Space Center has studied different concepts of crew and equipment translation aids. (Ref 15) Therefore, an area of interest is in the dynamic effects of this loading on the space station structure. However, the design of a control system proved to be a challenging task in itself so these dynamic effects due to

crew translation were not studied. The modeling of this dynamic loading would be a challenging area to study in itself. Therefore, it is recommended that the effects of this loading on a uncontrolled structure be considered for study before studying the effects on a structure with a control system in place.

APPENDIX A

Structural Modes (Eigenvectors)

Eigenvalue = 0.0000 REAL EIGENVECTOR NO. 1
Radian = 0.0000

NODE	ROW	TX	TY	TZ	RX	RY	RZ
1126	1)	1.1570E-02	-5.4379E-11	-1.4453E-12	-1.8830E-13	-3.7774E-12	-6.6299E-12
15040	7)	1.1570E-02	-5.2834E-11	3.1877E-12	-1.8830E-13	-3.7774E-12	-6.6299E-12
15000	13)	1.1570E-02	-5.2834E-11	1.0287E-11	-1.8830E-13	-3.7774E-12	-6.6299E-12
1100	19)	1.1570E-02	-5.2834E-11	1.5543E-11	-1.8830E-13	-3.7774E-12	-6.6299E-12
74	25)	1.1570E-02	-5.2834E-11	1.8645E-11	-1.8830E-13	-3.7774E-12	-6.6299E-12
64	31)	1.1570E-02	3.0896E-12	-6.1728E-12	-1.7295E-13	-3.8081E-12	-6.6064E-12
55	37)	1.1570E-02	0.0000	0.0000	0.0000	0.0000	0.0000
56	43)	1.1570E-02	3.0969E-12	-7.4749E-15	-1.4671E-13	-4.3455E-12	-6.3124E-12
51	49)	1.1570E-02	1.9031E-14	3.0528E-12	-2.7659E-13	-3.5691E-12	-7.3341E-12
52	55)	1.1570E-02	3.1056E-12	3.0491E-12	-1.7880E-13	-3.8577E-12	-6.7086E-12
13032	61)	1.1570E-02	-7.1337E-11	5.3835E-11	-1.8747E-13	-3.7870E-12	-6.6341E-12
44	67)	1.1570E-02	3.1130E-12	9.1756E-12	-1.8673E-13	-3.7872E-12	-6.6357E-12
16020	73)	1.1570E-02	-5.2835E-11	4.3304E-11	-1.8743E-13	-3.7868E-12	-6.6339E-12
13008	79)	1.1570E-02	-7.1337E-11	5.7490E-11	-1.8747E-13	-3.7870E-12	-6.6341E-12
32	85)	1.1570E-02	3.1136E-12	1.8394E-11	-1.8741E-13	-3.7869E-12	-6.6340E-12
23	91)	1.1570E-02	3.9146E-14	2.4543E-11	-1.8742E-13	-3.7869E-12	-6.6340E-12
24	97)	1.1570E-02	3.1136E-12	2.4543E-11	-1.8742E-13	-3.7869E-12	-6.6340E-12
16030	103)	1.1570E-02	1.5764E-12	2.9154E-11	-1.8742E-13	-3.7869E-12	-6.6340E-12
12	109)	1.1570E-02	3.1136E-12	3.3766E-11	-1.8742E-13	-3.7869E-12	-6.6340E-12
1	115)	1.1570E-02	-5.2835E-11	7.0975E-11	-1.8742E-13	-3.7869E-12	-6.6340E-12
13051	121)	1.1570E-02	-2.6041E-10	1.6176E-10	-1.8747E-13	-3.7870E-12	-6.6341E-12
13049	127)	1.1570E-02	-2.2060E-10	1.4087E-10	-1.8747E-13	-3.7870E-12	-6.6341E-12
13000	133)	1.1570E-02	-2.6041E-10	1.6542E-10	-1.8747E-13	-3.7870E-12	-6.6341E-12
13011	139)	1.1570E-02	1.9403E-10	-9.3990E-11	-1.8746E-13	-3.7870E-12	-6.6341E-12
13050	145)	1.1570E-02	1.5422E-10	-7.3096E-11	-1.8746E-13	-3.7870E-12	-6.6341E-12
13039	151)	1.1570E-02	1.9403E-10	-9.7646E-11	-1.8746E-13	-3.7870E-12	-6.6341E-12
13061	157)	1.1570E-02	1.5083E-10	-7.4924E-11	-1.8746E-13	-3.7870E-12	-6.6341E-12
1200	163)	1.1570E-02	-5.2835E-11	7.4050E-11	-1.8742E-13	-3.7869E-12	-6.6340E-12
15010	169)	1.1570E-02	-5.2835E-11	7.9281E-11	-1.8742E-13	-3.7869E-12	-6.6340E-12
15050	175)	1.1570E-02	-5.2835E-11	8.6347E-11	-1.8742E-13	-3.7869E-12	-6.6340E-12
1226	181)	1.1570E-02	-5.4373E-11	9.0959E-11	-1.8742E-13	-3.7869E-12	-6.6340E-12

Eigenvalue = 0.0000 REAL EIGENVECTOR NO. 2
Radian = 0.0000

NODE	ROW	TX	TY	TZ	RX	RY	RZ
1126	1)	1.4326E-10	1.1570E-02	3.3822E-09	1.9567E-11	-1.4589E-12	-4.9160E-13
15040	7)	1.1920E-10	1.1570E-02	2.9007E-09	1.9567E-11	-1.4589E-12	-4.9160E-13
15000	13)	1.0066E-10	1.1570E-02	2.1630E-09	1.9567E-11	-1.4589E-12	-4.9160E-13
1100	19)	8.6939E-11	1.1570E-02	1.6168E-09	1.9567E-11	-1.4589E-12	-4.9160E-13
74	25)	7.8841E-11	1.1570E-02	1.2945E-09	1.9567E-11	-1.4589E-12	-4.9160E-13
64	31)	5.0781E-11	1.1570E-02	6.4190E-10	1.9278E-11	-1.4419E-12	-5.1916E-13
55	37)	5.8557E-11	1.1570E-02	0.0000	0.0000	0.0000	0.0000
56	43)	3.4676E-11	1.1570E-02	1.4902E-14	2.1652E-11	-1.7854E-12	-4.1459E-13
51	49)	5.0489E-11	1.1570E-02	3.2093E-10	2.1601E-11	-1.6732E-12	-4.7263E-13
52	55)	2.6617E-11	1.1570E-02	-3.2094E-10	1.9084E-11	-1.3607E-12	-5.1170E-13
13032	61)	-8.4654E-12	1.1570E-02	-1.0462E-09	1.9580E-11	-1.4583E-12	-4.8342E-13
44	67)	1.0528E-11	1.1570E-02	-9.6309E-10	1.9566E-11	-1.4558E-12	-4.8834E-13
16020	73)	1.4517E-11	1.1570E-02	-1.2723E-09	1.9578E-11	-1.4582E-12	-4.8737E-13
13008	79)	-1.7893E-11	1.1570E-02	-1.4280E-09	1.9580E-11	-1.4582E-12	-4.8342E-13
32	85)	-1.3391E-11	1.1570E-02	-1.9266E-09	1.9578E-11	-1.4586E-12	-4.8721E-13
23	91)	-5.4419E-12	1.1570E-02	-2.5690E-09	1.9578E-11	-1.4586E-12	-4.8700E-13
24	97)	-2.9369E-11	1.1570E-02	-2.5690E-09	1.9578E-11	-1.4586E-12	-4.8701E-13
16030	103)	-2.9389E-11	1.1570E-02	-3.0507E-09	1.9578E-11	-1.4586E-12	-4.8701E-13
12	109)	-5.3336E-11	1.1570E-02	-3.5325E-09	1.9578E-11	-1.4586E-12	-4.8701E-13
1	115)	-5.7350E-11	1.1570E-02	-4.1628E-09	1.9578E-11	-1.4586E-12	-4.8701E-13
13051	121)	-8.4655E-12	1.1570E-02	-1.0047E-09	1.9580E-11	-1.4583E-12	-4.8346E-13
13049	127)	-1.3179E-11	1.1570E-02	-1.2043E-09	1.9580E-11	-1.4582E-12	-4.8346E-13
13000	133)	-1.7893E-11	1.1570E-02	-1.3865E-09	1.9580E-11	-1.4582E-12	-4.8346E-13
13011	139)	-1.7893E-11	1.1570E-02	-1.4864E-09	1.9580E-11	-1.4582E-12	-4.8345E-13
13050	145)	-1.3179E-11	1.1570E-02	-1.2867E-09	1.9580E-11	-1.4582E-12	-4.8346E-13
13039	151)	-8.4655E-12	1.1570E-02	-1.1046E-09	1.9580E-11	-1.4583E-12	-4.8345E-13
13061	157)	1.7929E-11	1.1570E-02	-1.0958E-09	1.9580E-11	-1.4583E-12	-4.8345E-13
1200	163)	-6.5339E-11	1.1570E-02	-4.4840E-09	1.9578E-11	-1.4586E-12	-4.8701E-13
15010	169)	-7.8932E-11	1.1570E-02	-5.0305E-09	1.9578E-11	-1.4586E-12	-4.8701E-13
15050	175)	-9.7294E-11	1.1570E-02	-5.7686E-09	1.9578E-11	-1.4586E-12	-4.8701E-13
1226	181)	-9.7314E-11	1.1570E-02	-6.2504E-09	1.9578E-11	-1.4586E-12	-4.8701E-13

Eigenvalue = 0.0000 REAL EIGENVECTOR NO. 3
Radian = 0.0000

NODE	ROW	TX	TY	TZ	RX	RY	RZ
1126	1)	-6.3754E-10	2.2289E-09	1.1570E-02	4.4742E-11	-8.7986E-13	2.7100E-12
15040	7)	-5.7808E-10	1.8619E-09	1.1570E-02	4.4742E-11	-8.7986E-13	2.7100E-12
15000	13)	-4.7590E-10	1.8619E-09	1.1570E-02	4.4742E-11	-8.7986E-13	2.7100E-12
1100	19)	-4.0026E-10	1.8619E-09	1.1570E-02	4.4742E-11	-8.7986E-13	2.7100E-12
74	25)	-3.5562E-10	1.8619E-09	1.1570E-02	4.4742E-11	-8.7986E-13	2.7100E-12
64	31)	-2.7411E-10	1.4727E-09	1.1570E-02	4.4074E-11	-8.2196E-13	2.6342E-12
55	37)	-1.7084E-10	2.2066E-09	1.1570E-02	0.0000	0.0000	0.0000
56	43)	-1.8517E-10	1.4727E-09	1.1570E-02	4.9474E-11	-1.2570E-12	2.7033E-12
51	49)	-1.2636E-10	2.2067E-09	1.1570E-02	4.9442E-11	-1.5128E-12	3.1607E-12
52	55)	-1.4075E-10	1.4726E-09	1.1570E-02	4.3641E-11	-6.1352E-13	2.7043E-12
13032	61)	-4.8159E-11	9.9794E-10	1.1570E-02	4.4766E-11	-8.9106E-13	2.7099E-12
44	67)	-5.1912E-11	1.4725E-09	1.1570E-02	4.4739E-11	-8.8494E-13	2.7075E-12
16020	73)	-1.6411E-13	1.8619E-09	1.1570E-02	4.4763E-11	-8.9084E-13	2.7095E-12
13008	79)	4.6841E-12	9.9794E-10	1.1570E-02	4.4766E-11	-8.9109E-13	2.7099E-12
32	85)	8.1429E-11	1.4725E-09	1.1570E-02	4.4764E-11	-8.9096E-13	2.7095E-12
23	91)	1.8494E-10	2.2068E-09	1.1570E-02	4.4764E-11	-8.9097E-13	2.7095E-12
24	97)	1.7032E-10	1.4725E-09	1.1570E-02	4.4764E-11	-8.9097E-13	2.7095E-12
16030	103)	2.4430E-10	1.8397E-09	1.1570E-02	4.4764E-11	-8.9097E-13	2.7095E-12
12	109)	3.0366E-10	1.4725E-09	1.1570E-02	4.4764E-11	-8.9097E-13	2.7095E-12
1	115)	3.9987E-10	1.8619E-09	1.1570E-02	4.4764E-11	-8.9097E-13	2.7095E-12
13051	121)	-4.8159E-11	1.0752E-09	1.1570E-02	4.4766E-11	-8.9106E-13	2.7099E-12
13049	127)	-2.1737E-11	1.0589E-09	1.1570E-02	4.4766E-11	-8.9107E-13	2.7099E-12
13000	133)	4.6841E-12	1.0752E-09	1.1570E-02	4.4766E-11	-8.9107E-13	2.7099E-12
13011	139)	4.6840E-12	8.8955E-10	1.1570E-02	4.4766E-11	-8.9109E-13	2.7099E-12
13050	145)	-2.1738E-11	9.0581E-10	1.1570E-02	4.4766E-11	-8.9109E-13	2.7099E-12
13039	151)	-4.8159E-11	8.8955E-10	1.1570E-02	4.4766E-11	-8.9108E-13	2.7099E-12
13061	157)	-3.2031E-11	1.7161E-09	1.1570E-02	4.4766E-11	-8.9108E-13	2.7099E-12
1200	163)	4.4431E-10	1.8619E-09	1.1570E-02	4.4764E-11	-8.9097E-13	2.7095E-12
15010	169)	5.1994E-10	1.8619E-09	1.1570E-02	4.4764E-11	-8.9097E-13	2.7095E-12
15050	175)	6.2210E-10	1.8619E-09	1.1570E-02	4.4764E-11	-8.9097E-13	2.7095E-12
1226	181)	6.9608E-10	2.2290E-09	1.1570E-02	4.4764E-11	-8.9097E-13	2.7095E-12

Eigenvalue = 0.0000 REAL EIGENVECTOR NO. 4
Radian = 0.0000

NODE	ROW	TX	TY	TZ	RX	RY	RZ
1126	1)	9.6723E-12	3.2294E-03	3.6922E-02	1.5547E-04	8.9062E-13	-6.7103E-14
15040	7)	1.5326E-11	1.9542E-03	3.3097E-02	1.5547E-04	8.9062E-13	-6.7103E-14
15000	13)	1.2796E-11	1.9542E-03	2.7235E-02	1.5547E-04	8.9062E-13	-6.7103E-14
1100	19)	1.0923E-11	1.9542E-03	2.2896E-02	1.5547E-04	8.9062E-13	-6.7103E-14
74	25)	9.8177E-12	1.9542E-03	2.0335E-02	1.5547E-04	8.9062E-13	-6.7103E-14
64	31)	1.4926E-11	6.7906E-04	1.5245E-02	1.5547E-04	8.8958E-13	-5.8358E-14
55	37)	-1.8790E-12	3.2294E-03	1.0144E-02	1.5547E-04	0.0000	0.0000
56	43)	1.2721E-11	6.7906E-04	1.0144E-02	1.5547E-04	1.0533E-12	-6.7159E-14
51	49)	-2.9846E-12	3.2294E-03	7.5938E-03	1.5547E-04	9.0485E-13	-8.8012E-14
52	55)	1.1626E-11	6.7906E-04	7.5938E-03	1.5547E-04	8.8065E-13	-6.4244E-14
13032	61)	1.9189E-11	-1.0777E-03	1.6994E-03	1.5547E-04	8.9291E-13	-6.7720E-14
44	67)	9.4375E-12	6.7906E-04	2.4932E-03	1.5547E-04	8.9233E-13	-6.7002E-14
16020	73)	1.0094E-12	1.9542E-03	-5.7137E-05	1.5547E-04	8.9286E-13	-6.7285E-14
13008	79)	1.7868E-11	-1.0777E-03	-1.3323E-03	1.5547E-04	8.9291E-13	-6.7720E-14
32	85)	6.1207E-12	6.7906E-04	-5.1578E-03	1.5547E-04	8.9293E-13	-6.7295E-14
23	91)	-1.0735E-11	3.2294E-03	-1.0258E-02	1.5547E-04	8.9293E-13	-6.7318E-14
24	97)	3.9122E-12	6.7906E-04	-1.0258E-02	1.5547E-04	8.9293E-13	-6.7317E-14
16030	103)	-5.0680E-12	1.9542E-03	-1.4084E-02	1.5547E-04	8.9293E-13	-6.7317E-14
12	109)	5.9940E-13	6.7906E-04	-1.7909E-02	1.5547E-04	8.9293E-13	-6.7317E-14
1	115)	-8.9330E-12	1.9542E-03	-2.3010E-02	1.5547E-04	8.9293E-13	-6.7317E-14
13051	121)	1.9189E-11	-1.0777E-03	1.6994E-03	1.5547E-04	8.9291E-13	-6.7716E-14
13049	127)	1.8529E-11	-1.0777E-03	1.8353E-04	1.5547E-04	8.9291E-13	-6.7716E-14
13000	133)	1.7868E-11	-1.0777E-03	-1.3323E-03	1.5547E-04	8.9291E-13	-6.7717E-14
13011	139)	1.7868E-11	-1.0777E-03	-1.3323E-03	1.5547E-04	8.9291E-13	-6.7716E-14
13050	145)	1.8529E-11	-1.0777E-03	1.8353E-04	1.5547E-04	8.9291E-13	-6.7716E-14
13039	151)	1.9189E-11	-1.0777E-03	1.6994E-03	1.5547E-04	8.9291E-13	-6.7716E-14
13061	157)	3.0272E-12	1.7363E-03	1.6994E-03	1.5547E-04	8.9291E-13	-6.7716E-14
1200	163)	-1.0037E-11	1.9542E-03	-2.5560E-02	1.5547E-04	8.9293E-13	-6.7317E-14
15010	169)	-1.1916E-11	1.9542E-03	-2.9900E-02	1.5547E-04	8.9293E-13	-6.7317E-14
15050	175)	-1.4454E-11	1.9542E-03	-3.5762E-02	1.5547E-04	8.9293E-13	-6.7317E-14
1226	181)	-2.3435E-11	3.2294E-03	-3.9587E-02	1.5547E-04	8.9293E-13	-6.7317E-14

Eigenvalue = 0.0000 REAL EIGENVECTOR NO. 5
Radian = 0.0000

NODE	ROW	TX	TY	TZ	RX	RY	RZ
1126	1)	-1.0724E-02	-7.9179E-05	-5.1132E-03	-3.8118E-06	5.1628E-04	-3.3571E-12
15040	7)	-6.4895E-03	-4.7914E-05	-5.0194E-03	-3.8118E-06	5.1628E-04	-3.3571E-12
15000	13)	-6.4895E-03	-4.7914E-05	-4.8757E-03	-3.8118E-06	5.1628E-04	-3.3571E-12
1100	19)	-6.4895E-03	-4.7914E-05	-4.7693E-03	-3.8118E-06	5.1628E-04	-3.3571E-12
74	25)	-6.4895E-03	-4.7914E-05	-4.7065E-03	-3.8118E-06	5.1628E-04	-3.3571E-12
64	31)	-2.2550E-03	-1.6649E-05	-3.4718E-04	-3.8118E-06	5.1628E-04	-3.3958E-12
55	37)	-1.0724E-02	-7.9179E-05	-2.2212E-04	-3.8118E-06	5.1628E-04	0.0000
56	43)	-2.2550E-03	-1.6649E-05	-2.2212E-04	-3.8118E-06	5.1628E-04	-3.4493E-12
51	49)	-1.0724E-02	-7.9179E-05	-1.5959E-04	-3.8118E-06	5.1628E-04	-3.7854E-12
52	55)	-2.2550E-03	-1.6649E-05	-1.5959E-04	-3.8118E-06	5.1628E-04	-3.3993E-12
13032	61)	3.5789E-03	2.6424E-05	-5.9740E-03	-3.8118E-06	5.1628E-04	-3.3638E-12
44	67)	-2.2550E-03	-1.6649E-05	-3.4532E-05	-3.8118E-06	5.1628E-04	-3.3670E-12
16020	73)	-6.4895E-03	-4.7914E-05	-4.2065E-03	-3.8118E-06	5.1628E-04	-3.3645E-12
13008	79)	3.5789E-03	2.6424E-05	-5.8996E-03	-3.8118E-06	5.1628E-04	-3.3638E-12
32	85)	-2.2550E-03	-1.6649E-05	1.5306E-04	-3.8118E-06	5.1628E-04	-3.3645E-12
23	91)	-1.0724E-02	-7.9179E-05	2.7811E-04	-3.8118E-06	5.1628E-04	-3.3645E-12
24	97)	-2.2550E-03	-1.6649E-05	2.7811E-04	-3.8118E-06	5.1628E-04	-3.3645E-12
16030	103)	-6.4895E-03	-4.7914E-05	3.7191E-04	-3.8118E-06	5.1628E-04	-3.3645E-12
12	107)	-2.2550E-03	-1.6649E-05	4.6570E-04	-3.8118E-06	5.1628E-04	-3.3645E-12
1	113)	-6.4895E-03	-4.7914E-05	-3.6438E-03	-3.8118E-06	5.1628E-04	-3.3645E-12
13051	121)	3.5789E-03	2.6424E-05	-2.0688E-02	-3.8118E-06	5.1628E-04	-3.3638E-12
13049	127)	3.5789E-03	2.6424E-05	-1.7553E-02	-3.8118E-06	5.1628E-04	-3.3638E-12
13000	133)	3.5789E-03	2.6424E-05	-2.0614E-02	-3.8118E-06	5.1628E-04	-3.3638E-12
13011	139)	3.5789E-03	2.6424E-05	1.4752E-02	-3.8118E-06	5.1628E-04	-3.3638E-12
13050	145)	3.5789E-03	2.6424E-05	1.1617E-02	-3.8118E-06	5.1628E-04	-3.3638E-12
13039	151)	3.5789E-03	2.6424E-05	1.4677E-02	-3.8118E-06	5.1628E-04	-3.3638E-12
13061	157)	-5.7657E-03	-4.2570E-05	1.1580E-02	-3.8118E-06	5.1628E-04	-3.3638E-12
1200	163)	-6.4895E-03	-4.7914E-05	-3.5812E-03	-3.8118E-06	5.1628E-04	-3.3645E-12
15010	169)	-6.4895E-03	-4.7914E-05	-3.4748E-03	-3.8118E-06	5.1628E-04	-3.3645E-12
15050	175)	-6.4895E-03	-4.7914E-05	-3.3311E-03	-3.8118E-06	5.1628E-04	-3.3645E-12
1226	181)	-1.0724E-02	-7.9179E-05	-3.2373E-03	-3.8118E-06	5.1628E-04	-3.3645E-12

Eigenvalue = 0.0000 REAL EIGENVECTOR NO. 6
Radian = 0.0000

NODE	ROW	TX	TY	TZ	RX	RY	RZ
1126	1)	-3.6369E-02	1.2711E-03	2.6201E-04	1.1616E-06	1.6995E-06	1.5299E-04
15040	7)	-3.2591E-02	1.2616E-03	2.3343E-04	1.1616E-06	1.6995E-06	1.5299E-04
15000	13)	-2.6823E-02	1.2616E-03	1.8964E-04	1.1616E-06	1.6995E-06	1.5299E-04
1100	19)	-2.2552E-02	1.2616E-03	1.5721E-04	1.1616E-06	1.6995E-06	1.5299E-04
74	25)	-2.0032E-02	1.2616E-03	1.3808E-04	1.1616E-06	1.6995E-06	1.5299E-04
64	31)	-1.5009E-02	-2.8077E-06	1.1399E-04	1.1616E-06	1.6995E-06	1.5299E-04
55	37)	-1.0018E-02	1.6247E-05	7.5880E-05	1.1616E-06	1.6995E-06	1.5299E-04
56	43)	-9.9900E-03	-2.8077E-06	7.5880E-05	1.1616E-06	1.6995E-06	1.5299E-04
51	49)	-7.5082E-03	1.6247E-05	5.6825E-05	1.1616E-06	1.6995E-06	1.5299E-04
52	55)	-7.4803E-03	-2.8077E-06	5.6825E-05	1.1616E-06	1.6995E-06	1.5299E-04
13032	61)	-1.6605E-03	1.7499E-03	-6.8316E-06	1.1616E-06	1.6995E-06	1.5299E-04
44	67)	-2.4609E-03	-2.8077E-06	1.8715E-05	1.1616E-06	1.6995E-06	1.5299E-04
16020	73)	3.4861E-05	1.2616E-03	-1.4279E-05	1.1616E-06	1.6995E-06	1.5299E-04
13008	79)	1.3229E-03	1.7499E-03	-2.9483E-05	1.1616E-06	1.6995E-06	1.5299E-04
32	85)	5.0682E-03	-2.8077E-06	-3.8449E-05	1.1616E-06	1.6995E-06	1.5299E-04
23	91)	1.0060E-02	1.6247E-05	-7.6559E-05	1.1616E-06	1.6995E-06	1.5299E-04
24	97)	1.0088E-02	-2.8077E-06	-7.6559E-05	1.1616E-06	1.6995E-06	1.5299E-04
16030	103)	1.3838E-02	6.7197E-06	-1.0514E-04	1.1616E-06	1.6995E-06	1.5299E-04
12	109)	1.7617E-02	-2.8077E-06	-1.3372E-04	1.1616E-06	1.6995E-06	1.5299E-04
1	115)	2.2622E-02	1.2616E-03	-1.8577E-04	1.1616E-06	1.6995E-06	1.5299E-04
13051	121)	-1.6605E-03	6.1102E-03	-5.5268E-05	1.1616E-06	1.6995E-06	1.5299E-04
13049	127)	-1.6883E-04	5.1922E-03	-5.6396E-05	1.1616E-06	1.6995E-06	1.5299E-04
13000	133)	1.3229E-03	6.1102E-03	-7.7919E-05	1.1616E-06	1.6995E-06	1.5299E-04
13011	139)	1.3229E-03	-4.3698E-03	3.8498E-05	1.1616E-06	1.6995E-06	1.5299E-04
13050	145)	-1.6883E-04	-3.4518E-03	3.9626E-05	1.1616E-06	1.6995E-06	1.5299E-04
13039	151)	-1.6605E-03	-4.3698E-03	6.1149E-05	1.1616E-06	1.6995E-06	1.5299E-04
13061	157)	-1.6913E-03	-3.4308E-03	5.0952E-05	1.1616E-06	1.6995E-06	1.5299E-04
1200	163)	2.5132E-02	1.2616E-03	-2.0483E-04	1.1616E-06	1.6995E-06	1.5299E-04
15010	169)	2.9402E-02	1.2616E-03	-2.3725E-04	1.1616E-06	1.6995E-06	1.5299E-04
15050	175)	3.5171E-02	1.2616E-03	-2.8105E-04	1.1616E-06	1.6995E-06	1.5299E-04
1226	181)	3.8921E-02	1.2711E-03	-3.0963E-04	1.1616E-06	1.6995E-06	1.5299E-04

Eigenvalue = 1.5055E+00 REAL EIGENVECTOR NO. 7
Radian = 1.2270E+00

NODE	ROW	TX	TY	TZ	RX	RY	RZ
1126	1)	-1.1148E-02	2.6951E-03	4.6700E-02	3.1090E-04	-5.7317E-05	7.3162E-05
15040	7)	-9.8176E-03	1.4526E-04	3.9050E-02	3.1088E-04	-5.7310E-05	7.3159E-05
15000	13)	-7.0432E-03	1.5995E-04	2.7322E-02	3.0638E-04	-5.5490E-05	7.2288E-05
1100	19)	-4.9969E-03	1.8514E-04	1.8824E-02	2.9246E-04	-4.7981E-05	7.0399E-05
74	25)	-3.9427E-03	1.8513E-04	1.4470E-02	2.3355E-04	-4.8064E-05	5.6905E-05
64	31)	-2.3786E-03	-1.7799E-03	6.7541E-03	2.1366E-04	-3.6412E-05	5.5272E-05
55	37)	-4.0261E-04	1.1340E-03	8.2666E-04	1.5117E-04	-1.9139E-05	3.8561E-05
56	43)	-7.0645E-04	-1.2204E-03	7.9550E-04	1.6028E-04	-1.8717E-05	4.2726E-05
51	49)	1.1657E-04	9.6331E-04	-1.4768E-03	1.2073E-04	-8.6072E-06	3.0690E-05
52	55)	-2.2537E-05	-8.8463E-04	-1.5046E-03	1.2699E-04	-7.7742E-06	3.4471E-05
13032	61)	1.3082E-03	-1.3650E-04	-4.7709E-03	1.9168E-05	2.0013E-05	3.3946E-07
44	67)	9.7181E-04	-1.4692E-04	-4.3976E-03	4.4057E-05	1.5474E-05	1.4643E-05
16020	73)	9.3681E-04	2.9156E-04	-4.9664E-03	1.9508E-05	2.0445E-05	2.2210E-06
13008	79)	1.3153E-03	-1.3707E-04	-5.1433E-03	1.8865E-05	2.0082E-05	3.9533E-07
32	85)	1.1300E-03	9.2268E-04	-4.0881E-03	-7.2170E-05	5.2342E-05	-1.4645E-05
23	91)	-7.8249E-04	-5.4308E-04	-7.9105E-04	-1.2717E-04	8.2135E-05	-3.3949E-05
24	97)	5.8401E-04	1.5568E-03	-7.6218E-04	-1.4169E-04	8.5546E-05	-3.1819E-05
16030	103)	-1.0503E-03	5.4532E-04	2.9210E-03	-1.5787E-04	9.7227E-05	-4.3125E-05
12	109)	-1.2425E-03	2.0316E-03	7.1575E-03	-2.0131E-04	1.1363E-04	-4.6512E-05
1	115)	-3.7833E-03	1.5990E-04	1.2741E-02	-2.0611E-04	1.3082E-04	-4.9831E-05
13051	121)	1.3083E-03	-1.2616E-04	-5.3418E-03	1.9161E-05	2.0047E-05	3.7203E-07
13049	127)	1.3118E-03	-1.2828E-04	-5.4082E-03	1.9124E-05	2.0036E-05	3.6218E-07
13000	133)	1.3154E-03	-1.2593E-04	-5.7145E-03	1.9040E-05	2.0026E-05	3.7181E-07
13011	139)	1.3151E-03	-1.5105E-04	-4.3398E-03	1.8859E-05	2.0054E-05	3.4112E-07
13050	145)	1.3117E-03	-1.4905E-04	-4.2759E-03	1.8947E-05	2.0025E-05	3.6718E-07
13039	151)	1.3080E-03	-1.5143E-04	-3.9707E-03	1.9041E-05	1.9997E-05	3.8822E-07
13061	157)	9.4614E-04	1.9559E-04	-4.0908E-03	1.9046E-05	1.9989E-05	3.8829E-07
1200	163)	-4.7066E-03	1.6002E-04	1.6568E-02	-2.5802E-04	1.3242E-04	-6.2105E-05
15010	169)	-6.5098E-03	1.3764E-04	2.4070E-02	-2.7067E-04	1.4190E-04	-6.3466E-05
15050	175)	-8.9468E-03	1.2460E-04	3.4430E-02	-2.7465E-04	1.4350E-04	-6.4252E-05
1226	181)	-1.1705E-02	-2.1284E-03	4.1189E-02	-2.7466E-04	1.4350E-04	-6.4255E-05

Eigenvalue = 1.6069E+00 REAL EIGENVECTOR NO. 8
Radian = 1.2676E+00

NODE	ROW	TX	TY	TZ	RX	RY	RZ
1126	1)	-4.6575E-02	-7.4835E-04	-1.0789E-02	-7.8554E-05	1.2805E-05	3.1443E-04
15040	7)	-3.8732E-02	-1.0392E-04	-8.8566E-03	-7.8549E-05	1.2803E-05	3.1441E-04
15000	13)	-2.6880E-02	-9.4279E-05	-5.9112E-03	-7.7131E-05	9.6504E-06	3.0947E-04
1100	19)	-1.8269E-02	-7.7731E-05	-3.8032E-03	-7.2975E-05	1.1055E-06	2.9704E-04
74	25)	-1.3820E-02	-7.7380E-05	-2.7144E-03	-5.8591E-05	1.1526E-06	2.4027E-04
64	31)	-6.3360E-03	-1.3113E-03	-1.0582E-03	-5.0776E-05	-1.7895E-05	2.2083E-04
55	37)	4.9184E-04	-1.6878E-03	1.9888E-04	-3.4886E-05	-4.6883E-05	1.6932E-04
56	43)	-2.5411E-04	-9.6184E-04	2.0957E-04	-3.7302E-05	-4.7536E-05	1.6625E-04
51	49)	3.1266E-03	-1.3717E-03	6.4956E-04	-2.7400E-05	-6.4360E-05	1.3946E-04
52	55)	2.0898E-03	-7.5095E-04	6.6131E-04	-2.8881E-05	-6.5958E-05	1.3235E-04
13032	61)	3.9008E-03	3.9042E-04	2.4009E-03	-1.0186E-05	-1.1429E-04	2.5361E-05
44	67)	5.0457E-03	-2.6254E-04	1.1108E-03	-9.9343E-06	-1.0632E-04	4.8476E-05
16020	73)	6.4574E-03	2.6131E-05	2.1460E-03	-9.3414E-06	-1.1465E-04	2.1503E-05
13008	79)	4.3961E-03	3.8857E-04	2.6014E-03	-1.0212E-05	-1.1443E-04	2.5378E-05
32	85)	4.5663E-03	4.3968E-04	7.8638E-04	2.0254E-05	-1.7215E-04	-8.0152E-05
23	91)	4.6124E-03	1.1975E-03	-3.3713E-04	3.5589E-05	-2.2450E-04	-1.1618E-04
24	97)	8.8354E-04	8.1315E-04	-3.5554E-04	4.1792E-05	-2.3250E-04	-1.4969E-04
16030	103)	-1.0271E-03	1.2276E-03	-1.3754E-03	3.3745E-05	-2.5393E-04	-1.7072E-04
12	109)	-7.6828E-03	1.0583E-03	-2.5027E-03	5.5089E-05	-2.7965E-04	-2.1533E-04
1	115)	-1.2247E-02	-1.4893E-04	-1.8720E-03	5.3458E-05	-3.0889E-04	-2.1667E-04
13051	121)	3.9007E-03	1.1125E-03	5.6588E-03	-1.0345E-05	-1.1434E-04	2.5346E-05
13049	127)	4.1481E-03	9.6019E-04	5.0738E-03	-1.0369E-05	-1.1434E-04	2.5402E-05
13000	133)	4.3959E-03	1.1125E-03	5.8608E-03	-1.0326E-05	-1.1434E-04	2.5422E-05
13011	139)	4.3960E-03	-6.2562E-04	-1.9781E-03	-1.0114E-05	-1.1451E-04	2.5360E-05
13050	145)	4.1487E-03	-4.7347E-04	-1.3895E-03	-1.0082E-05	-1.1451E-04	2.5382E-05
13039	151)	3.9010E-03	-6.2596E-04	-2.1747E-03	-1.0054E-05	-1.1451E-04	2.5412E-05
13061	157)	5.9747E-03	-6.5558E-04	-1.4877E-03	-1.0064E-05	-1.1460E-04	2.5417E-05
1200	163)	-1.6238E-02	-1.4874E-04	-2.8569E-03	6.6032E-05	-3.1181E-04	-2.6729E-04
15010	169)	-2.4001E-02	-1.6391E-04	-4.7759E-03	7.1056E-05	-3.3014E-04	-2.7984E-04
15050	175)	-3.4718E-02	-1.7273E-04	-7.4870E-03	7.2314E-05	-3.3302E-04	-2.8429E-04
1226	181)	-3.8983E-02	4.2032E-04	-9.2665E-03	7.2320E-05	-3.3304E-04	-2.8431E-04

Eigenvalue = 6.8928E+00 REAL EIGENVECTOR NO. 9
Radian = 2.6254E+00

NODE	ROW	TX	TY	TZ	RX	RY	RZ
1126	1)	-3.6590E-02	-3.9255E-03	-1.1672E-02	-1.5782E-04	8.3777E-04	3.5049E-04
15040	7)	-2.1093E-02	-2.6308E-03	-7.7882E-03	-1.5779E-04	8.3771E-04	3.5043E-04
15000	13)	-7.9906E-03	-2.6088E-03	-1.9374E-03	-1.5016E-04	8.2537E-04	3.3390E-04
1100	19)	8.7587E-04	-2.5746E-03	1.7588E-03	-1.1542E-04	6.8154E-04	2.8561E-04
74	25)	4.5576E-03	-2.5679E-03	3.2115E-03	-6.0354E-05	6.5151E-04	1.5713E-04
64	31)	1.2393E-02	-2.9310E-03	8.1179E-03	1.6713E-05	4.2862E-04	6.7307E-05
55	37)	7.8917E-03	-2.1821E-03	6.3631E-03	4.9104E-05	2.4435E-04	1.0396E-05
56	43)	1.1708E-02	-2.3921E-03	6.1944E-03	7.5981E-05	2.0447E-04	-7.5692E-05
51	49)	8.0978E-03	-1.5812E-03	4.8900E-03	6.6061E-05	1.3120E-04	-4.4305E-05
52	55)	1.0066E-02	-2.0927E-03	4.7156E-03	1.0504E-04	8.9432E-05	-1.5897E-04
13032	61)	2.1020E-03	-3.5790E-03	1.6727E-03	6.8915E-05	-1.1590E-04	-3.3721E-04
44	67)	4.2630E-03	-1.3935E-03	6.9088E-04	1.1033E-04	-1.1261E-04	-3.7300E-04
16020	73)	5.1397E-04	-2.5330E-03	5.9554E-04	6.7780E-05	-1.0982E-04	-1.9975E-04
13008	79)	-4.4603E-03	-3.5832E-03	3.4702E-04	6.8272E-05	-1.1823E-04	-3.3717E-04
32	85)	-6.3128E-03	-2.1480E-03	-1.2322E-03	4.9479E-05	1.2316E-05	-1.2910E-04
23	91)	-9.8744E-03	-2.2091E-03	-1.3814E-03	4.4913E-06	1.2588E-04	-5.4357E-05
24	97)	-7.6343E-03	-2.6800E-03	-1.3127E-03	-2.1810E-06	1.5070E-04	-7.9302E-06
16030	103)	-8.5304E-03	-2.8011E-03	-1.1794E-03	1.1294E-05	2.0456E-04	3.6079E-05
12	109)	-5.0804E-03	-3.0960E-03	-7.5577E-04	-4.0779E-05	2.8886E-04	1.4156E-04
1	115)	-3.7542E-03	-2.5319E-03	-2.3466E-03	-3.0037E-05	3.8261E-04	1.3229E-04
13051	121)	2.1011E-03	-1.3179E-02	4.9893E-03	6.6578E-05	-1.1675E-04	-3.3660E-04
13049	127)	-1.1797E-03	-1.1160E-02	3.6418E-03	6.6222E-05	-1.1700E-04	-3.3641E-04
13000	133)	-4.4596E-03	-1.3178E-02	3.6995E-03	6.6342E-05	-1.1725E-04	-3.3644E-04
13011	139)	-4.4619E-03	9.8986E-03	-4.3844E-03	7.1314E-05	-1.1806E-04	-3.3685E-04
13050	145)	-1.1784E-03	7.8779E-03	-2.9794E-03	7.1599E-05	-1.1758E-04	-3.3672E-04
13039	151)	2.1047E-03	9.8990E-03	-2.9821E-03	7.2000E-05	-1.1710E-04	-3.3678E-04
13061	157)	4.2275E-03	9.1876E-03	-2.2798E-03	7.2521E-05	-1.1739E-04	-3.3707E-04
1200	163)	-6.8802E-04	-2.5382E-03	-1.6366E-03	-5.5898E-05	4.0010E-04	2.3802E-04
15010	169)	6.6409E-03	-2.5161E-03	1.5116E-04	-7.4155E-05	4.8765E-04	2.7388E-04
15050	175)	1.7385E-02	-2.4997E-03	3.0290E-03	-7.7958E-05	4.9648E-04	2.8734E-04
1226	181)	2.0385E-02	-3.1391E-03	4.9477E-03	-7.7977E-05	4.9655E-04	2.8739E-04

Eigenvalue = 8.4367E+00 REAL EIGENVECTOR NO. 10
Radian = 2.9046E+00

NODE	ROW	TX	TY	TZ	RX	RY	RZ
1126	1)	7.9349E-04	-1.6363E-03	1.1544E-02	1.7475E-04	-1.2669E-03	8.0024E-05
15040	7)	-7.6268E-03	-3.0692E-03	7.2429E-03	1.7471E-04	-1.2667E-03	8.0016E-05
15000	13)	-4.5939E-03	-3.0388E-03	7.1336E-04	1.6638E-04	-1.2645E-03	7.4920E-05
1100	19)	-2.0269E-03	-2.9940E-03	-3.2530E-03	1.1640E-04	-1.0390E-03	9.1871E-05
74	25)	-9.8203E-04	-2.9857E-03	-4.6611E-03	5.4803E-05	-9.8258E-04	3.2387E-05
64	31)	-5.2676E-03	-3.1694E-03	-1.1198E-02	-7.0736E-05	-6.6095E-04	1.2284E-04
55	37)	4.9593E-03	-3.4730E-03	-8.2612E-03	-7.9164E-05	-4.2652E-04	-1.1499E-05
56	43)	-1.7738E-03	-2.6056E-03	-7.9379E-03	-1.4074E-04	-3.7712E-04	9.2945E-05
51	49)	4.1292E-03	-3.4687E-03	-6.1347E-03	-9.1902E-05	-2.8911E-04	-2.7888E-05
52	55)	-3.4454E-04	-2.3187E-03	-5.8028E-03	-1.7177E-04	-2.4088E-04	5.9807E-05
13032	61)	2.0176E-03	-5.7144E-04	-5.4977E-04	-9.8730E-05	1.6984E-05	-1.5839E-04
44	67)	1.3948E-03	-1.7291E-03	-1.3223E-03	-1.9974E-04	-1.9689E-05	-1.0473E-04
16020	73)	-1.7370E-04	-2.9571E-03	6.9960E-04	-7.9696E-05	1.4404E-05	-6.4618E-05
13008	79)	-1.0626E-03	-5.7426E-04	1.3872E-03	-9.9011E-05	1.6470E-05	-1.5839E-04
32	85)	-1.5174E-03	-2.3960E-03	4.8902E-03	-1.1555E-04	2.1421E-04	-2.7186E-05
23	91)	-7.7033E-03	-2.9610E-03	7.3044E-03	-3.0742E-05	3.8430E-04	-5.9216E-05
24	97)	-1.0611E-03	-2.9930E-03	7.5299E-03	-6.1885E-05	4.2816E-04	2.3739E-05
16030	103)	-4.6575E-03	-3.1179E-03	7.9523E-03	1.9263E-05	5.1920E-04	-4.1314E-06
12	109)	4.9064E-04	-3.5784E-03	8.0808E-03	1.2494E-05	6.4710E-04	7.1678E-05
1	115)	-3.8033E-03	-3.1464E-03	1.1197E-03	6.3312E-05	8.0697E-04	4.1164E-05
13051	121)	2.0171E-03	-5.0806E-03	-1.0293E-03	-9.9437E-05	1.6737E-05	-1.5807E-04
13049	127)	4.7687E-04	-4.1325E-03	4.1636E-05	-9.9611E-05	1.6749E-05	-1.5791E-04
13000	133)	-1.0628E-03	-5.0804E-03	9.1225E-04	-9.9569E-05	1.6760E-05	-1.5794E-04
13011	139)	-1.0629E-03	5.7546E-03	2.0418E-03	-9.8340E-05	1.6410E-05	-1.5808E-04
13050	145)	4.7807E-04	4.8063E-03	9.8458E-04	-9.8300E-05	1.6591E-05	-1.5803E-04
13039	151)	2.0189E-03	5.7548E-03	1.2764E-04	-9.8096E-05	1.6771E-05	-1.5805E-04
13061	157)	1.7166E-03	3.0325E-03	2.7017E-05	-9.7986E-05	1.6676E-05	-1.5822E-04
1200	163)	-3.0042E-03	-3.1547E-03	-8.7543E-04	1.7710E-04	8.5161E-04	5.6551E-05
15010	169)	-1.0879E-03	-3.1298E-03	-6.2001E-03	1.8624E-04	1.0144E-03	8.3106E-05
15050	175)	2.1407E-03	-3.1084E-03	-1.3604E-02	1.9779E-04	1.0106E-03	8.6193E-05
1226	181)	-4.0271E-03	-1.4855E-03	-1.8474E-02	1.9782E-04	1.0107E-03	8.6215E-05

Eigenvalue = 9.5676E+00 REAL EIGENVECTOR NO. 11
Radian = 3.0932E+00

NODE	ROW	TX	TY	TZ	RX	RY	RZ
1126	1)	7.1934E-03	2.2412E-03	-2.3465E-02	-3.3093E-04	1.4787E-04	-9.3123E-05
15040	7)	6.1135E-03	4.9547E-03	-1.5320E-02	-3.3087E-04	1.4784E-04	-9.3107E-05
15000	13)	2.5796E-03	4.9041E-03	-2.9766E-03	-3.1211E-04	1.4095E-04	-8.7976E-05
1100	19)	3.7301E-05	4.8329E-03	5.2071E-03	-2.5968E-04	9.3611E-05	-8.1692E-05
74	25)	-8.8101E-04	4.8182E-03	8.1861E-03	-9.9246E-05	8.6190E-05	-2.7971E-05
64	31)	-1.5149E-03	4.9205E-03	1.0635E-02	-2.4826E-05	1.3423E-05	-2.8214E-05
55	37)	-1.2419E-03	5.0538E-03	9.7173E-03	5.9902E-05	-4.6761E-05	2.8635E-05
56	43)	-1.9724E-03	3.9406E-03	9.6635E-03	1.1196E-04	-5.6921E-05	2.2885E-05
51	49)	-5.1043E-04	5.1981E-03	8.2181E-03	9.2062E-05	-7.6962E-05	4.8709E-05
52	55)	-1.7826E-03	3.4527E-03	8.1513E-03	1.9747E-04	-9.1836E-05	6.5625E-05
13032	61)	-2.6526E-03	-1.8484E-05	4.0303E-03	2.2852E-04	-1.6837E-04	2.0150E-04
44	67)	-5.4554E-04	2.5150E-03	3.4682E-03	3.8250E-04	-1.4469E-04	2.2996E-04
16020	73)	3.1182E-03	4.8180E-03	8.5459E-04	1.8570E-04	-1.4809E-04	8.7603E-05
13008	79)	1.2631E-03	-1.6194E-05	-4.4158E-04	2.2905E-04	-1.6665E-04	2.0148E-04
32	85)	7.3085E-03	3.6410E-03	-5.1564E-03	1.8925E-04	7.5681E-05	1.5383E-04
23	91)	4.8421E-03	5.7185E-03	-6.9737E-03	3.1126E-05	3.4334E-04	-3.3184E-05
24	97)	1.0607E-02	4.7368E-03	-6.7245E-03	7.8610E-05	3.7479E-04	9.3895E-05
16030	103)	7.0997E-03	5.4807E-03	-6.9704E-03	1.4093E-05	5.1149E-04	-5.0835E-05
12	109)	1.1197E-02	5.8699E-03	-6.0715E-03	-9.8613E-05	7.0282E-04	-3.3085E-05
1	115)	2.8168E-03	5.1406E-03	-9.9551E-03	-8.7078E-05	9.3853E-04	-9.4274E-05
13051	121)	-2.6526E-03	5.7152E-03	8.8148E-03	2.3022E-04	-1.6761E-04	2.0093E-04
13049	127)	-6.9447E-04	4.5095E-03	5.5626E-03	2.3056E-04	-1.6744E-04	2.0077E-04
13000	133)	1.2632E-03	5.7146E-03	4.3181E-03	2.3054E-04	-1.6728E-04	2.0085E-04
13011	139)	1.2639E-03	-8.0634E-03	-7.1195E-03	2.2658E-04	-1.6747E-04	2.0093E-04
13050	145)	-6.9465E-04	-6.8581E-03	-3.9064E-03	2.2642E-04	-1.6791E-04	2.0084E-04
13039	151)	-2.6531E-03	-8.0638E-03	-2.7094E-03	2.2631E-04	-1.6835E-04	2.0092E-04
13061	157)	3.9573E-04	-2.7626E-03	-1.6997E-03	2.2632E-04	-1.6853E-04	2.0116E-04
1200	163)	1.3903E-04	5.1568E-03	-7.7252E-03	-1.8367E-04	9.9987E-04	-2.2760E-04
15010	169)	-6.5448E-03	5.1221E-03	-1.7656E-03	-2.4608E-04	1.2466E-03	-2.2586E-04
15050	175)	-1.5562E-02	5.0869E-03	7.8565E-03	-2.5835E-04	1.2458E-03	-2.4091E-04
1226	181)	-3.1713E-02	2.9669E-03	1.4216E-02	-2.5840E-04	1.2459E-03	-2.4095E-04

Eigenvalue = 1.2164E+01 REAL EIGENVECTOR NO. 12
Radian = 3.4876E+00

NODE	ROW	TX	TY	TZ	RX	RY	RZ
1126	1)	4.0530E-03	-9.2943E-04	-2.3229E-02	-3.3648E-04	-8.5276E-04	1.2221E-05
15040	7)	-2.6406E-03	1.8298E-03	-1.4947E-02	-3.3641E-04	-8.5269E-04	1.2219E-05
15000	13)	-2.2304E-03	1.7953E-03	-2.4729E-03	-3.1208E-04	-8.6590E-04	8.8744E-06
1100	19)	-1.6126E-03	1.7556E-03	6.0389E-03	-2.7790E-04	-6.8388E-04	2.7904E-05
74	25)	-1.3803E-03	1.7491E-03	8.9469E-03	-7.0802E-05	-6.2946E-04	-1.3975E-06
64	31)	-4.4494E-03	1.6575E-03	7.2048E-03	-9.4435E-05	-3.8633E-04	1.0387E-04
55	37)	1.1615E-03	2.2718E-03	7.8352E-03	4.0181E-05	-2.2987E-04	-1.0987E-05
56	43)	-2.2183E-03	1.0451E-03	8.1110E-03	6.7021E-05	-1.9204E-04	9.2022E-05
51	49)	5.7383E-04	2.6592E-03	7.2387E-03	6.9400E-05	-1.2726E-04	-1.8794E-05
52	55)	-1.2138E-03	7.7968E-04	7.5011E-03	2.1420E-04	-1.0569E-04	6.2109E-05
13032	61)	1.7176E-03	-2.8227E-03	1.9019E-03	2.8095E-04	9.9244E-05	-9.3127E-05
44	67)	4.8738E-06	4.3935E-04	3.5669E-03	5.2701E-04	2.2236E-05	-8.1169E-05
16020	73)	-1.4414E-03	1.8449E-03	-8.8068E-04	2.1305E-04	7.1702E-05	-3.7198E-05
13008	79)	-9.3694E-05	-2.8249E-03	-3.5590E-03	2.8030E-04	9.7435E-05	-9.3173E-05
32	85)	-3.5439E-03	6.6697E-04	-9.5746E-03	5.7859E-04	-9.1609E-05	-1.3340E-04
23	91)	-2.3739E-03	3.1294E-03	-1.6549E-02	1.2537E-04	-1.6788E-04	4.3896E-06
24	97)	-5.5455E-03	1.2607E-03	-1.6836E-02	3.9644E-04	-2.2541E-04	-1.0681E-04
16030	103)	-4.1372E-03	2.1573E-03	-1.9461E-02	6.0471E-05	-2.5938E-04	1.0697E-06
12	109)	-6.3694E-03	2.1375E-03	-2.0835E-02	4.6385E-05	-2.9710E-04	2.0881E-05
1	115)	-2.8455E-03	2.2228E-03	-1.6248E-02	-1.2369E-04	-3.5129E-04	4.1956E-05
13051	121)	1.7158E-03	-5.4707E-03	-9.1263E-04	2.7906E-04	9.8443E-05	-9.2811E-05
13049	127)	8.1138E-04	-4.9140E-03	-3.0405E-03	2.7866E-04	9.8267E-05	-9.2720E-05
13000	133)	-9.2475E-05	-5.4703E-03	-6.3459E-03	2.7870E-04	9.8092E-05	-9.2697E-05
13011	139)	-9.6495E-05	9.0694E-04	3.5136E-04	2.8283E-04	9.8225E-05	-9.3239E-05
13050	145)	8.1214E-04	3.4794E-04	2.5211E-03	2.8314E-04	9.8831E-05	-9.3176E-05
13039	151)	1.7210E-03	9.0810E-04	5.8800E-03	2.8350E-04	9.9437E-05	-9.3286E-05
13061	157)	-7.9958E-05	5.4887E-03	5.2847E-03	2.8433E-04	9.9562E-05	-9.3429E-05
1200	163)	-1.4493E-03	2.2300E-03	-1.1434E-02	-4.5902E-04	-3.7967E-04	1.2584E-04
15010	169)	2.4015E-03	2.1971E-03	3.0288E-03	-5.5425E-04	-4.1593E-04	1.4030E-04
15050	175)	8.0445E-03	2.1606E-03	2.5129E-02	-5.9719E-04	-3.8773E-04	1.5440E-04
1226	181)	1.5025E-02	-2.7392E-03	3.9832E-02	-5.9732E-04	-3.8770E-04	1.5444E-04

Eigenvalue = 1.6803E+01 REAL EIGENVECTOR NO. 13
Radian = 4.0991E+00

NODE	ROW	TX	TY	TZ	RX	RY	RZ
1126	1)	2.0819E-04	5.5308E-05	3.1756E-04	5.1760E-06	2.5720E-06	-3.1365E-06
15040	7)	1.5208E-04	1.2856E-05	1.9015E-04	5.1746E-06	2.5722E-06	-3.1355E-06
15000	13)	3.7426E-05	1.2943E-05	7.6034E-07	4.6727E-06	2.9935E-06	-2.7865E-06
1100	19)	-3.6811E-05	1.2861E-05	-1.1659E-04	3.5781E-06	2.8946E-06	-2.2653E-06
74	25)	-5.6271E-05	1.2771E-05	-1.4565E-04	-8.9724E-08	2.6483E-06	-3.9537E-08
64	31)	-1.4042E-05	1.6885E-05	-8.7718E-05	-3.7310E-03	6.0104E-04	3.7546E-03
55	37)	-3.0260E-05	-1.9421E-05	6.3129E-06	1.4757E-03	-4.7704E-04	8.9174E-04
56	43)	6.5078E-05	1.7390E-05	1.8952E-05	-1.5190E-02	2.4304E-03	1.5325E-02
51	49)	6.0958E-06	2.4441E-06	5.5531E-05	-6.5857E-04	1.1287E-03	-9.3469E-04
52	55)	8.7300E-05	1.6887E-05	5.6497E-05	1.5002E-02	-2.7020E-03	-1.5158E-02
13032	61)	-1.5111E-05	9.8098E-06	-6.9718E-06	-4.3375E-07	-8.7276E-08	1.0315E-06
44	67)	-2.3150E-06	1.2561E-05	-3.4358E-08	1.9886E-03	-3.5818E-04	-2.1584E-03
16020	73)	-1.6082E-06	9.9478E-06	-3.6517E-06	-3.9624E-07	-7.3323E-08	1.0021E-07
13008	79)	4.8769E-06	9.8419E-06	1.3586E-06	-4.3266E-07	-6.9026E-08	1.0314E-06
32	85)	1.8917E-05	1.5101E-05	2.2083E-05	-9.9587E-06	1.3876E-06	3.9328E-06
23	91)	2.2555E-05	1.5197E-06	5.7463E-05	-3.6996E-07	4.1060E-07	4.3156E-07
24	97)	3.3221E-05	1.5214E-05	5.8577E-05	-8.5229E-06	1.5647E-06	3.4379E-06
16030	103)	3.4367E-05	8.7385E-06	7.9348E-05	-7.0064E-07	6.9454E-07	2.1691E-07
12	109)	4.2813E-05	1.3009E-05	9.5113E-05	-3.6185E-06	7.3465E-07	3.7126E-07
1	115)	3.6014E-05	1.0006E-05	9.6295E-05	1.9556E-07	1.3974E-07	-2.1479E-07
13051	121)	-1.5101E-05	3.9111E-05	-4.6065E-06	-4.1619E-07	-7.9982E-08	1.0259E-06
13049	127)	-5.1097E-06	3.2960E-05	-1.0437E-06	-4.1383E-07	-7.8360E-08	1.0240E-06
13000	133)	4.8744E-06	3.9111E-05	3.4581E-06	-4.1591E-07	-7.6738E-08	1.0245E-06
13011	139)	4.8926E-06	-3.1359E-05	-1.4197E-06	-4.5531E-07	-7.2279E-08	1.0280E-06
13050	145)	-5.1237E-06	-2.5194E-05	-5.4320E-06	-4.5681E-07	-7.6650E-08	1.0269E-06
13039	151)	-1.5139E-05	-3.1364E-05	-1.0382E-06	-4.5904E-07	-8.1021E-08	1.0277E-06
13061	157)	-1.3692E-05	-3.3564E-05	-9.8996E-06	-4.6401E-07	-7.9433E-08	1.0299E-06
1200	163)	2.7290E-05	1.0067E-05	7.8794E-05	1.9369E-06	1.2312E-07	-8.4160E-07
15010	169)	6.1565E-08	1.0239E-05	1.5241E-05	2.5817E-06	-4.5696E-07	-1.0808E-06
15050	175)	-4.3740E-05	1.0426E-05	-8.8826E-05	2.8419E-06	-6.5071E-07	-1.2074E-06
1226	181)	-6.8126E-05	3.3745E-05	-1.5880E-04	2.8427E-06	-6.5132E-07	-1.2078E-06

Eigenvalue = 1.7009E+01 REAL EIGENVECTOR NO. 14
Radian = 4.1242E+00

NODE	ROW	TX	TY	TZ	RX	RY	RZ
1126	1)	2.4067E-04	-1.6254E-05	-2.9382E-04	-4.7046E-06	-1.0830E-06	-3.1993E-06
15040	7)	1.5301E-04	2.2314E-05	-1.7800E-04	-4.7033E-06	-1.0833E-06	-3.1984E-06
15000	13)	3.3974E-05	2.1107E-05	-4.2199E-06	-4.2711E-06	-1.1453E-06	-2.8911E-06
1100	19)	-4.3056E-05	1.9689E-05	1.0402E-04	-3.2376E-06	-1.0144E-06	-2.2960E-06
74	25)	-6.2786E-05	1.9555E-05	1.2942E-04	1.8972E-07	-9.3277E-07	-4.4100E-08
64	31)	-5.4636E-05	-5.0366E-06	9.3747E-05	3.6791E-03	-5.2240E-06	3.6236E-03
55	37)	1.8211E-05	3.5153E-05	1.2487E-05	-1.4595E-03	-3.4715E-05	8.6154E-04
56	43)	1.4037E-05	-7.9830E-06	6.5095E-06	1.5287E-02	-1.4895E-05	1.5108E-02
51	49)	4.5055E-05	2.9038E-05	-4.2695E-05	4.5306E-04	8.6529E-04	-1.1313E-03
52	55)	6.6889E-05	4.5851E-05	-5.5243E-05	-1.5157E-02	1.3874E-05	-1.5003E-02
13032	61)	-1.2335E-05	4.5193E-06	7.6424E-06	4.0140E-07	6.6342E-09	1.0621E-06
44	67)	-5.5157E-06	1.9961E-05	6.8970E-06	-2.5286E-03	-1.6715E-05	-2.6814E-03
16020	73)	-1.8013E-06	1.9507E-05	3.9792E-06	4.6849E-07	-1.4691E-08	2.7536E-07
13008	79)	8.2059E-06	4.6049E-06	-4.0825E-07	4.1569E-07	2.4637E-08	1.0596E-06
32	85)	1.7162E-05	1.1926E-05	-2.4610E-05	1.0977E-05	-9.1826E-07	2.9970E-06
23	91)	3.4294E-05	2.7795E-05	-6.0222E-05	2.7721E-07	-1.5651E-07	4.4898E-07
24	97)	2.8946E-05	1.4557E-05	-6.1090E-05	9.7327E-06	-9.1468E-07	2.3391E-06
16030	103)	3.6526E-05	2.2681E-05	-8.1962E-05	6.4972E-07	-2.7756E-07	9.7327E-08
12	109)	3.7459E-05	2.1282E-05	-9.7656E-05	4.2495E-06	-3.4851E-07	5.2245E-07
1	115)	3.4313E-05	2.4426E-05	-1.0212E-04	-2.2884E-07	1.9429E-07	-2.5132E-07
13051	121)	-1.2336E-05	3.4688E-05	7.3384E-06	4.2198E-07	1.3473E-08	1.0556E-06
13049	127)	-2.0586E-06	2.8357E-05	3.2808E-06	4.2634E-07	1.5451E-08	1.0530E-06
13000	133)	8.2052E-06	3.4676E-05	-9.8747E-07	4.2716E-07	1.7429E-08	1.0529E-06
13011	139)	8.2179E-06	-3.7765E-05	5.6219E-07	3.9074E-07	2.1800E-08	1.0569E-06
13050	145)	-2.0712E-06	-3.1424E-05	4.2140E-06	3.8513E-07	1.8416E-08	1.0541E-06
13039	151)	-1.2344E-05	-3.7747E-05	8.0310E-06	3.7932E-07	1.5032E-08	1.0536E-06
13061	157)	-1.2636E-05	-2.4591E-05	7.9436E-06	3.7682E-07	1.6664E-08	1.0559E-06
1200	163)	2.4910E-05	2.4560E-05	-8.3817E-05	-2.0036E-06	2.3600E-07	-8.8627E-07
15010	169)	-2.4486E-06	2.4328E-05	-1.8342E-05	-2.6587E-06	7.3204E-07	-9.9664E-07
15050	175)	-4.2926E-05	2.3959E-05	8.8708E-05	-2.9147E-06	8.1489E-07	-1.0878E-06
1226	181)	-7.6403E-05	4.0167E-08	1.6048E-04	-2.9154E-06	8.1510E-07	-1.0880E-06

Eigenvalue = 1.8349E+01 REAL EIGENVECTOR NO. 15
Radian = 4.2836E+00

NODE	ROW	TX	TY	TZ	RX	RY	RZ
1126	1)	-2.5688E-04	2.5207E-04	1.4363E-03	2.6146E-05	1.6373E-05	2.4837E-06
15040	7)	-6.1406E-05	3.7682E-05	7.9266E-04	2.6139E-05	1.6373E-05	2.4833E-06
15000	13)	3.4405E-05	4.0698E-05	-1.6415E-04	2.3624E-05	1.7565E-05	2.3912E-06
1100	19)	8.9493E-05	4.2845E-05	-7.5800E-04	1.8435E-05	1.3928E-05	1.5316E-06
74	25)	1.0788E-04	4.2639E-05	-9.1912E-04	1.1090E-06	1.2422E-05	7.2268E-07
64	31)	1.8195E-04	7.9169E-05	-7.7562E-04	-2.6186E-04	3.5556E-05	4.8558E-05
55	37)	5.1714E-05	-3.4260E-05	-5.5714E-04	-9.6083E-06	4.8615E-06	-9.2999E-07
56	43)	1.2840E-04	1.0576E-04	-5.5878E-04	-6.9550E-05	1.1016E-05	-3.2032E-06
51	49)	5.3831E-05	-4.6443E-05	-4.0665E-04	5.3588E-06	1.1086E-06	1.2572E-06
52	55)	9.6826E-05	1.0882E-04	-4.0711E-04	-1.0371E-04	1.0918E-05	4.6257E-06
13032	61)	-6.5859E-05	1.5361E-04	6.3251E-06	-1.1474E-05	-3.9848E-06	9.7062E-06
44	67)	3.8610E-05	8.8357E-05	-4.6780E-05	-1.3863E-04	1.1392E-05	2.0614E-05
16020	73)	1.3402E-04	2.2960E-05	1.1789E-04	-7.6824E-06	-2.9821E-06	-5.3372E-07
13008	79)	1.2238E-04	1.5385E-04	2.2818E-04	-1.1386E-05	-3.7760E-06	9.7034E-06
32	85)	-5.3811E-05	9.6129E-05	1.9950E-04	1.7685E-02	-3.2347E-03	-1.9635E-02
23	91)	-3.2152E-04	1.4552E-04	5.0139E-05	-6.5379E-04	5.4722E-04	-6.5601E-04
24	97)	-5.0981E-04	6.9974E-05	4.9822E-05	1.0357E-02	-2.0158E-03	-1.1640E-02
16030	103)	-7.0778E-04	9.2067E-05	-9.0910E-05	4.7626E-06	-1.0416E-05	-7.9769E-06
12	109)	-9.1007E-04	2.9786E-05	-1.4657E-04	4.0152E-05	-1.1884E-05	-8.8249E-05
1	115)	-8.9217E-04	2.7663E-05	-1.9123E-04	7.5148E-07	9.5816E-06	3.7822E-06
13051	121)	-6.5749E-05	4.2919E-04	1.1839E-04	-1.1257E-05	-3.8980E-06	9.6494E-06
13049	127)	2.8272E-05	3.7128E-04	2.0452E-04	-1.1215E-05	-3.8736E-06	9.6390E-06
13000	133)	1.2225E-04	4.2911E-04	3.3692E-04	-1.1214E-05	-3.8492E-06	9.6406E-06
13011	139)	1.2265E-04	-2.3429E-04	7.6032E-05	-1.1686E-05	-3.8462E-06	9.6889E-06
13050	145)	2.8262E-05	-1.7620E-04	-1.4989E-05	-1.1721E-05	-3.9070E-06	9.6768E-06
13039	151)	-6.6121E-05	-2.3437E-04	-1.5328E-04	-1.1764E-05	-3.9677E-06	9.6875E-06
13061	157)	5.7688E-06	-3.9001E-04	-1.2952E-04	-1.1839E-05	-3.9756E-06	9.7099E-06
1200	163)	-6.8923E-04	2.7595E-05	-1.7687E-04	-2.5157E-06	1.1761E-05	2.0762E-05
15010	169)	-1.7147E-06	3.1742E-05	-7.7424E-05	-5.2164E-06	2.4329E-05	2.7123E-05
15050	175)	1.1065E-03	3.5468E-05	1.3150E-04	-5.9209E-06	2.6272E-05	3.0248E-05
1226	181)	1.6358E-03	-1.3058E-05	2.7724E-04	-5.9240E-06	2.6284E-05	3.0258E-05

Eigenvalue = 1.8549E+01 REAL EIGENVECTOR NO. 16
Radian = 4.3068E+00

NODE	ROW	TX	TY	TZ	RX	RY	RZ
1126	1)	-1.0497E-04	-3.7558E-05	1.2742E-03	2.3423E-05	1.3204E-05	2.8993E-07
15040	7)	1.0509E-05	-2.2962E-04	6.9763E-04	2.3417E-05	1.3204E-05	2.9002E-07
15000	13)	2.6435E-05	-2.2620E-04	-1.5964E-04	2.1139E-05	1.4382E-05	4.0119E-07
1100	19)	3.3227E-05	-2.2261E-04	-6.9059E-04	1.6397E-05	1.1750E-05	5.9388E-10
74	25)	3.3479E-05	-2.2133E-04	-8.3340E-04	9.4178E-07	1.0516E-05	5.7561E-08
64	31)	9.2275E-05	-1.8234E-04	-7.0176E-04	-7.7144E-04	1.0455E-04	3.3212E-04
55	37)	-3.3091E-05	-2.7965E-04	-5.0120E-04	-2.1124E-05	4.0240E-06	-3.6701E-06
56	43)	5.0340E-05	-1.5677E-04	-5.0137E-04	-6.1663E-05	9.5874E-06	-3.7048E-05
51	49)	-3.2806E-05	-2.8613E-04	-3.6747E-04	1.9905E-05	-2.8669E-06	5.1635E-06
52	55)	2.5985E-05	-1.5314E-04	-3.6624E-04	-2.1298E-04	2.7966E-05	7.5190E-05
13032	61)	1.8547E-05	1.5739E-05	-5.0886E-05	-1.0663E-05	6.2209E-07	-7.6191E-06
44	67)	-8.3218E-06	-1.6201E-04	-9.7397E-05	-2.2443E-04	1.3208E-05	-7.2029E-05
16020	73)	-8.4884E-05	-2.3995E-04	7.8180E-05	-6.4580E-06	9.3415E-07	1.4470E-06
13008	79)	-1.2912E-04	1.5639E-05	1.5774E-04	-1.0660E-05	5.2770E-07	-7.6207E-06
32	85)	6.5541E-05	-3.6626E-04	2.5763E-04	2.0027E-02	-1.8105E-04	1.7900E-02
23	91)	4.4512E-04	-2.7852E-04	7.8408E-05	-5.7453E-04	-2.5206E-04	6.6273E-04
24	97)	5.0723E-04	-3.6058E-04	8.4987E-05	1.0947E-02	-2.5349E-05	9.9849E-03
16030	103)	7.4972E-04	-2.8647E-04	-7.1240E-05	3.0169E-06	4.8558E-06	6.5322E-06
12	109)	9.1917E-04	-2.7366E-04	-1.5287E-04	5.0865E-05	8.6752E-06	1.1313E-04
1	115)	8.7431E-04	-2.3715E-04	-2.2912E-04	5.2779E-07	8.7321E-07	-3.9498E-06
13051	121)	1.8561E-05	-2.0084E-04	-6.7970E-05	-1.0753E-05	5.8508E-07	-7.5832E-06
13049	127)	-5.5305E-05	-1.5535E-04	4.0445E-05	-1.0763E-05	5.7746E-07	-7.5718E-06
13000	133)	-1.2915E-04	-2.0083E-04	1.4193E-04	-1.0752E-05	5.6984E-07	-7.5781E-06
13011	139)	-1.2909E-04	3.1939E-04	1.7888E-04	-1.0537E-05	5.4896E-07	-7.5768E-06
13050	145)	-5.5248E-05	2.7395E-04	7.2844E-05	-1.0538E-05	5.7091E-07	-7.5727E-06
13039	151)	1.8601E-05	3.1942E-04	-2.6339E-05	-1.0536E-05	5.9287E-07	-7.5770E-06
13061	157)	7.8732E-06	8.3218E-05	-2.9908E-05	-1.0544E-05	5.9284E-07	-7.5948E-06
1200	163)	6.6157E-04	-2.3827E-04	-1.8821E-04	-5.4651E-06	6.9206E-07	-2.1738E-05
15010	169)	-4.6578E-05	-2.4571E-04	-2.4450E-06	-7.0848E-06	-1.7016E-06	-2.7000E-05
15050	175)	-1.1539E-03	-2.5202E-04	2.8851E-04	-7.7137E-06	-2.9498E-06	-3.0113E-05
1226	181)	-1.8713E-03	-3.1540E-04	4.7854E-04	-7.7149E-06	-2.9560E-06	-3.0123E-05

Eigenvalue = 1.8608E+01 REAL EIGENVECTOR NO. 17
Radian = 4.3137E+00

NODE	ROW	TX	TY	TZ	RX	RY	RZ
1126	1)	8.5765E-04	1.7184E-04	1.1236E-03	1.8918E-05	1.5049E-05	-1.4060E-05
15040	7)	6.3497E-04	1.6673E-05	6.5792E-04	1.8913E-05	1.5048E-05	-1.4055E-05
15000	13)	1.2232E-04	1.6700E-05	-3.1165E-05	1.6901E-05	1.6864E-05	-1.2390E-05
1100	19)	-2.0981E-04	1.6087E-05	-4.5452E-04	1.2882E-05	1.4317E-05	-1.0193E-05
74	25)	-2.9560E-04	1.5873E-05	-5.5051E-04	-1.3539E-06	1.2766E-05	1.0712E-08
64	31)	-1.1040E-04	3.2942E-05	-2.8611E-04	-2.1240E-02	3.7289E-03	2.1165E-02
55	37)	-1.4498E-04	-5.8208E-05	-3.9882E-05	-5.4159E-04	-1.2990E-04	-6.5058E-06
56	43)	2.2284E-05	2.9107E-05	-5.2632E-05	6.5729E-04	-1.5833E-05	-5.9654E-04
51	49)	-7.3477E-05	-4.6090E-05	1.9472E-05	5.0802E-04	-1.4314E-04	2.5193E-04
52	55)	4.6753E-05	2.3685E-05	1.7971E-05	-4.7546E-03	8.2942E-04	4.6973E-03
13032	61)	-1.2213E-05	-1.5337E-05	6.0740E-05	1.4761E-06	-1.7513E-06	-2.9545E-07
44	67)	2.1872E-05	7.4312E-06	5.2921E-05	-1.4112E-03	2.7326E-04	1.7105E-03
16020	73)	2.2082E-05	7.8282E-06	4.0616E-05	8.8944E-07	-1.4029E-06	-2.8676E-07
13008	79)	-1.7976E-05	-1.5366E-05	3.1932E-05	1.4894E-06	-1.7726E-06	-2.9687E-07
32	85)	-2.3953E-05	-6.6923E-06	-6.6571E-05	-6.9842E-04	3.1190E-05	-3.1192E-04
23	91)	-1.2885E-05	4.8565E-05	-1.9986E-04	2.1227E-05	3.1140E-08	-1.3478E-05
24	97)	-6.2014E-05	-7.7765E-06	-2.0362E-04	-3.4393E-04	1.1305E-05	-1.7706E-04
16030	103)	-6.1626E-05	2.0544E-05	-2.9056E-04	3.1116E-06	-2.6381E-06	-8.9294E-07
12	109)	-9.2241E-05	2.2730E-06	-3.6231E-04	7.5653E-05	-8.8008E-06	-1.6478E-05
1	115)	-8.3197E-05	1.6883E-05	-3.9217E-04	-2.9210E-07	8.5552E-07	2.6821E-07
13051	121)	-1.2227E-05	-2.3770E-05	1.1073E-04	1.4601E-06	-1.7575E-06	-2.9609E-07
13049	127)	-1.5106E-05	-2.2005E-05	8.5944E-05	1.4613E-06	-1.7594E-06	-2.9453E-07
13000	133)	-1.7974E-05	-2.3781E-05	8.2235E-05	1.4681E-06	-1.7613E-06	-2.9411E-07
13011	139)	-1.7974E-05	-3.4677E-06	-3.9114E-05	1.5087E-06	-1.7758E-06	-2.9765E-07
13050	145)	-1.5074E-05	-5.2507E-06	-1.3752E-05	1.5081E-06	-1.7726E-06	-2.9743E-07
13039	151)	-1.2173E-05	-3.4620E-06	-9.6700E-06	1.5070E-06	-1.7694E-06	-2.9762E-07
13061	157)	1.9916E-05	2.2090E-05	9.4704E-07	1.5128E-06	-1.7754E-06	-2.9832E-07
1200	163)	-6.7284E-05	1.6956E-05	-3.3121E-04	-7.1679E-06	1.1704E-06	1.6632E-06
15010	169)	-9.5575E-06	1.6571E-05	-9.2851E-05	-9.9282E-06	4.4372E-06	2.4660E-06
15050	175)	9.0996E-05	1.5816E-05	3.0855E-04	-1.1002E-05	5.1480E-06	2.8051E-06
1226	181)	1.1781E-04	-7.4462E-05	5.7945E-04	-1.1005E-05	5.1506E-06	2.8063E-06

Eigenvalue = 1.8803E+01 REAL EIGENVECTOR NO. 18
Radian = 4.3363E+00

NODE	ROW	TX	TY	TZ	RX	RY	RZ
1126	1)	-1.3334E-03	2.7609E-04	1.3523E-03	2.3190E-05	3.1387E-06	1.9631E-05
15040	7)	-8.2436E-04	8.5986E-05	7.8138E-04	2.3184E-05	3.1403E-06	1.9625E-05
15000	13)	-9.8996E-05	9.1731E-05	-7.1996E-05	2.0932E-05	3.2571E-06	1.7606E-05
1100	19)	3.6501E-04	9.7265E-05	-5.9259E-04	1.5526E-05	3.0746E-06	1.4032E-05
74	25)	4.9032E-04	9.6912E-05	-7.0941E-04	-1.4278E-06	2.8916E-06	9.3515E-07
64	31)	4.4943E-04	2.1524E-04	-5.2079E-04	-2.1061E-02	-1.8396E-06	-2.1109E-02
55	37)	1.8988E-04	5.4090E-05	-1.8985E-04	-6.1896E-04	2.6540E-04	-1.8487E-04
56	43)	2.2392E-04	1.6280E-04	-1.9701E-04	3.1751E-04	-6.1852E-06	2.3330E-04
51	49)	1.1470E-04	5.3318E-05	-7.3708E-05	5.3384E-04	-4.0987E-05	-1.9856E-04
52	55)	1.3437E-04	1.4707E-04	-7.1974E-05	-4.5962E-03	3.6317E-06	-4.5752E-03
13032	61)	-3.4219E-05	9.3786E-06	8.4350E-05	1.8289E-06	-1.3032E-06	3.0620E-06
44	67)	6.2448E-06	7.9988E-05	7.5006E-05	-2.7790E-03	-4.5524E-05	-3.2426E-03
16020	73)	2.5533E-05	6.5341E-05	6.1144E-05	1.0189E-06	-1.2612E-06	-3.1267E-07
13008	79)	2.5006E-05	9.5932E-06	4.8015E-05	1.8754E-06	-1.2583E-06	3.0553E-06
32	85)	3.0713E-05	3.8557E-05	-9.4881E-05	-3.8458E-04	2.3362E-05	-8.4019E-05
23	91)	8.4858E-05	1.3051E-04	-3.1334E-04	9.7163E-06	-2.4968E-06	-4.1790E-06
24	97)	2.3825E-05	3.9759E-05	-3.1933E-04	-1.2260E-04	3.1914E-06	-4.8396E-05
16030	103)	4.6893E-05	8.9465E-05	-4.6459E-04	4.9756E-06	-3.2709E-06	-5.0100E-07
12	109)	2.2027E-05	6.5543E-05	-5.8459E-04	1.9551E-04	-2.1041E-05	-3.7665E-05
1	115)	2.5517E-05	9.2107E-05	-6.4057E-04	-4.3503E-07	1.1752E-06	-3.9522E-07
13051	121)	-3.4228E-05	9.6330E-05	1.2114E-04	1.8834E-06	-1.2839E-06	3.0422E-06
13049	127)	-4.6027E-06	7.8075E-05	9.4996E-05	1.8971E-06	-1.2785E-06	3.0358E-06
13000	133)	2.4991E-05	9.6288E-05	8.4103E-05	1.9030E-06	-1.2732E-06	3.0358E-06
13011	139)	2.5057E-05	-1.1253E-04	-2.5224E-06	1.8060E-06	-1.2714E-06	3.0462E-06
13050	145)	-4.6043E-06	-9.4252E-05	2.2646E-05	1.7916E-06	-1.2816E-06	3.0392E-06
13039	151)	-3.4227E-05	-1.1248E-04	3.2284E-05	1.7751E-06	-1.2919E-06	3.0382E-06
13061	157)	-1.0841E-05	-6.2202E-05	4.0050E-05	1.7696E-06	-1.2927E-06	3.0454E-06
1200	163)	1.4709E-05	9.2639E-05	-5.4115E-04	-1.1734E-05	1.5878E-06	-9.1290E-07
15010	169)	-7.3948E-06	9.1864E-05	-1.5186E-04	-1.6170E-05	6.0696E-06	-4.8929E-07
15050	175)	-2.7257E-05	9.0202E-05	5.0214E-04	-1.7907E-05	6.9633E-06	-4.4979E-07
1226	181)	-9.5497E-05	-5.6745E-05	9.4307E-04	-1.7912E-05	6.9664E-06	-4.4944E-07

Eigenvalue = 1.9097E+01 REAL EIGENVECTOR NO. 19
Radian = 4.3700E+00

NODE	ROW	TX	TY	TZ	RX	RY	RZ
1126	1)	1.5180E-04	-1.0845E-04	-8.3996E-04	-1.5602E-05	-8.9438E-06	-1.5539E-06
15040	7)	4.0165E-05	1.9482E-05	-4.5592E-04	-1.5598E-05	-8.9437E-06	-1.5536E-06
15000	13)	-1.9794E-05	1.7501E-05	1.1428E-04	-1.4051E-05	-9.6726E-06	-1.4872E-06
1100	19)	-5.4802E-05	1.5957E-05	4.6534E-04	-1.0848E-05	-7.6934E-06	-9.7633E-07
74	25)	-6.5862E-05	1.5842E-05	5.5797E-04	-4.0750E-07	-6.8433E-06	-3.7848E-07
64	31)	-1.0524E-04	-8.6369E-06	4.6533E-04	-2.0563E-04	6.2014E-06	-8.2367E-05
55	37)	-2.9616E-05	6.1246E-05	3.2573E-04	-6.3522E-06	-8.1675E-07	-4.2412E-07
56	43)	-7.2181E-05	-2.4947E-05	3.2585E-04	7.8712E-05	-8.2351E-06	1.3595E-05
51	49)	-2.8251E-05	6.7145E-05	2.3176E-04	1.6957E-06	-5.7615E-07	-1.1969E-06
52	55)	-5.2071E-05	-2.6119E-05	2.3130E-04	-1.2542E-06	-1.7725E-06	-1.3941E-05
13032	61)	2.9872E-05	-6.8084E-05	-1.0891E-05	6.4533E-06	1.9730E-06	-2.6919E-06
44	67)	-1.5538E-05	-1.3353E-05	2.3602E-05	1.3959E-04	-8.3871E-06	2.7776E-05
16020	73)	-4.3955E-05	2.8799E-05	-7.6893E-05	4.3324E-06	1.3656E-06	4.2504E-08
13008	79)	-2.2346E-05	-6.8188E-05	-1.3601E-04	6.4093E-06	1.9010E-06	-2.6899E-06
32	85)	-2.1517E-05	1.7714E-05	-1.6790E-04	1.4807E-04	-3.2282E-05	-2.2635E-04
23	91)	8.0733E-05	-4.3531E-05	-7.8216E-05	1.1749E-05	-3.6652E-06	1.0866E-05
24	97)	7.6326E-05	3.8606E-05	-8.0686E-05	-1.4787E-04	2.5725E-05	1.3559E-04
16030	103)	1.8966E-04	-9.1756E-06	7.2387E-05	-6.7951E-06	-1.6688E-06	4.3224E-06
12	109)	3.9301E-04	5.2208E-05	3.5004E-04	-2.1876E-02	3.7735E-03	2.1966E-02
1	115)	5.3135E-04	3.2632E-05	5.8725E-04	-2.8415E-06	-4.3588E-06	1.0522E-07
13051	121)	2.9825E-05	-1.4446E-04	-6.6581E-05	6.3758E-06	1.9421E-06	-2.6745E-06
13049	127)	3.7628E-06	-1.2841E-04	-1.1700E-04	6.3585E-06	1.9329E-06	-2.6719E-06
13000	133)	-2.2282E-05	-1.4443E-04	-1.9050E-04	6.3543E-06	1.9236E-06	-2.6710E-06
13011	139)	-2.2474E-05	3.9634E-05	-5.9439E-05	6.5169E-06	1.9295E-06	-2.6925E-06
13050	145)	3.7487E-06	2.3494E-05	-7.3980E-06	6.5335E-06	1.9513E-06	-2.6878E-06
13039	151)	2.9964E-05	3.9657E-05	6.8234E-05	6.5528E-06	1.9732E-06	-2.6912E-06
13061	157)	-5.7929E-06	1.4247E-04	5.6417E-05	6.5852E-06	1.9776E-06	-2.6976E-06
1200	163)	4.1226E-04	3.2991E-05	5.0960E-04	1.2235E-05	-5.8954E-06	-1.4373E-05
15010	169)	-8.0472E-05	3.1787E-05	7.8514E-05	1.8557E-05	-1.7891E-05	-1.9743E-05
15050	175)	-8.9375E-04	3.1078E-05	-6.7791E-04	2.0834E-05	-2.0331E-05	-2.2306E-05
1226	181)	-1.2762E-03	2.0201E-04	-1.1909E-03	2.0841E-05	-2.0342E-05	-2.2315E-05

Eigenvalue = 1.9289E+01 REAL EIGENVECTOR NO. 20
Radian = 4.3918E+00

NODE	ROW	TX	TY	TZ	RX	RY	RZ
1126	1)	1.6162E-04	-4.1489E-05	-8.8650E-04	-1.6592E-05	-8.4774E-06	-1.7405E-06
15040	7)	4.9208E-05	9.4560E-05	-4.7806E-04	-1.6588E-05	-8.4776E-06	-1.7402E-06
15000	13)	-1.8094E-05	9.2147E-05	1.2837E-04	-1.4934E-05	-9.2520E-06	-1.6562E-06
1100	19)	-5.8608E-05	8.9931E-05	5.0069E-04	-1.1464E-05	-7.5129E-06	-1.1336E-06
74	25)	-7.0460E-05	8.9377E-05	5.9813E-04	-3.8534E-07	-6.7042E-06	-3.1436E-07
64	31)	-1.0896E-04	6.0732E-05	4.9874E-04	-1.8257E-04	3.0167E-06	-9.3311E-05
55	37)	-2.3700E-05	1.3384E-04	3.4596E-04	-9.0213E-06	-1.2539E-06	2.3718E-06
56	43)	-7.2895E-05	4.2023E-05	3.4536E-04	1.2155E-04	-8.2798E-06	6.2358E-05
51	49)	-1.7546E-05	1.3842E-04	2.4452E-04	-3.7603E-06	2.7201E-06	-1.8868E-06
52	55)	-4.9730E-05	4.0501E-05	2.4322E-04	1.4506E-05	-3.6477E-06	-1.2109E-05
13032	61)	3.2478E-06	-2.9973E-05	2.7327E-06	6.6701E-06	6.0122E-07	1.6239E-06
44	67)	-8.0832E-06	5.1617E-05	3.6200E-05	3.2021E-04	-4.9045E-06	2.5351E-04
16020	73)	1.1142E-05	1.0306E-04	-7.3076E-05	4.4151E-06	3.5000E-07	-2.1436E-07
13008	79)	3.4731E-05	-3.0025E-05	-1.2722E-04	6.6441E-06	6.0466E-07	1.6268E-06
32	85)	-7.5526E-06	1.3937E-04	-1.7069E-04	1.7829E-04	5.4642E-06	2.3383E-04
23	91)	-1.3034E-04	9.2215E-05	-5.1889E-05	1.1145E-05	-1.7950E-06	-1.0385E-05
24	97)	-1.2681E-04	1.9008E-04	-5.1245E-05	-1.3465E-04	-3.3619E-06	-1.6938E-04
16030	103)	-2.4377E-04	1.4565E-04	1.2357E-04	-7.7992E-06	4.7971E-07	-4.2851E-06
12	109)	-4.3034E-04	2.1466E-04	3.8619E-04	-2.1957E-02	3.8520E-06	-2.1887E-02
1	115)	-5.6643E-04	7.3430E-05	6.4840E-04	-2.5109E-06	-1.6500E-06	5.1922E-07
13051	121)	3.2253E-06	1.6259E-05	-1.4395E-05	6.6669E-06	6.0105E-07	1.6193E-06
13049	127)	1.8998E-05	6.5490E-06	-7.5771E-05	6.6624E-06	5.9980E-07	1.6170E-06
13000	133)	3.4774E-05	1.6276E-05	-1.4429E-04	6.6556E-06	5.9854E-07	1.6202E-06
13011	139)	3.4657E-05	-9.4558E-05	-1.0281E-04	6.6466E-06	6.0880E-07	1.6083E-06
13050	145)	1.8967E-05	-8.4908E-05	-4.1610E-05	6.6561E-06	6.1057E-07	1.6099E-06
13039	151)	3.2641E-06	-9.4575E-05	2.7011E-05	6.6666E-06	6.1233E-07	1.6111E-06
13061	157)	-7.8431E-06	3.5933E-05	2.3346E-05	6.6843E-06	6.1461E-07	1.6150E-06
1200	163)	-4.2163E-04	7.3696E-05	5.5026E-04	1.4378E-05	-1.9106E-06	1.6815E-05
15010	169)	1.3507E-04	8.1555E-05	5.5553E-05	2.0083E-05	-4.1597E-06	2.0899E-05
15050	175)	9.9986E-04	8.8741E-05	-7.6648E-04	2.2288E-05	-4.0037E-06	2.3416E-05
1226	181)	1.6094E-03	2.7172E-04	-1.3154E-03	2.2294E-05	-4.0015E-06	2.3424E-05

Eigenvalue = 1.9435E+01 REAL EIGENVECTOR NO. 21
Radian = 4.4085E+00

NODE	ROW	TX	TY	TZ	RX	RY	RZ
1126	1)	1.4180E-04	-1.0788E-04	-7.2035E-04	-1.3458E-05	-7.4907E-06	-1.5680E-06
15040	7)	4.1743E-05	2.4681E-06	-3.8907E-04	-1.3455E-05	-7.4907E-06	-1.5677E-06
15000	13)	-1.8239E-05	7.7295E-07	1.0245E-04	-1.2102E-05	-8.1164E-06	-1.4857E-06
1100	19)	-5.3642E-05	-4.6191E-07	4.0387E-04	-9.2962E-06	-6.4429E-06	-1.0118E-06
74	25)	-6.5066E-05	-4.8046E-07	4.8208E-04	-2.1166E-07	-5.7209E-06	-3.8553E-07
64	31)	-9.8876E-05	-2.2235E-05	3.9758E-04	-1.5138E-04	1.7788E-06	-8.7511E-05
55	37)	-3.5764E-05	4.0467E-05	2.7166E-04	-1.1314E-05	-5.8713E-07	3.8997E-06
56	43)	-7.0640E-05	-3.5637E-05	2.7170E-04	1.4710E-04	-6.6730E-06	9.6064E-05
51	49)	-3.4311E-05	4.5555E-05	1.8830E-04	-8.5788E-06	6.1570E-06	-2.8429E-06
52	55)	-5.2814E-05	-3.5684E-05	1.8772E-04	2.1936E-05	-3.0468E-06	-6.8698E-06
13032	61)	2.1949E-05	-6.0009E-05	-2.3135E-05	5.1027E-06	1.8987E-06	-3.0785E-06
44	67)	-2.1312E-05	-2.2634E-05	7.4976E-06	4.7677E-04	-2.2346E-06	4.2931E-04
16020	73)	-5.4180E-05	1.1336E-05	-7.4075E-05	3.6116E-06	1.4020E-06	-8.7166E-08
13008	79)	-3.7721E-05	-6.0129E-05	-1.2188E-04	5.0569E-06	1.8264E-06	-3.0764E-06
32	85)	-4.7807E-05	-2.3888E-06	-1.5556E-04	1.0718E-02	-2.0352E-03	-1.1691E-02
23	91)	5.9480E-05	-9.7563E-05	-2.9371E-05	1.9607E-03	-6.4549E-04	9.7193E-04
24	97)	1.3049E-04	7.8663E-06	-7.7435E-06	-1.8302E-02	3.4789E-03	1.9552E-02
16030	103)	3.2830E-04	-4.5416E-05	2.5637E-04	-6.9745E-06	9.2280E-06	5.2501E-06
12	109)	4.9401E-04	1.5359E-05	3.9108E-04	2.1300E-04	-3.8669E-05	-2.6328E-04
1	115)	4.9520E-04	1.2575E-06	4.6217E-04	-9.9988E-07	-3.2702E-06	-1.1900E-06
13051	121)	2.1914E-05	-1.4738E-04	-7.6698E-05	5.0242E-06	1.8675E-06	-3.0585E-06
13049	127)	-7.8849E-06	-1.2902E-04	-1.1438E-04	5.0066E-06	1.8584E-06	-3.0547E-06
13000	133)	-3.7663E-05	-1.4734E-04	-1.7426E-04	5.0022E-06	1.8493E-06	-3.0543E-06
13011	139)	-3.7838E-05	6.3038E-05	-4.8299E-05	5.1653E-06	1.8553E-06	-3.0742E-06
13050	145)	-7.8980E-06	4.4609E-05	-8.9891E-06	5.1822E-06	1.8771E-06	-3.0688E-06
13039	151)	2.2032E-05	6.3058E-05	5.3023E-05	5.2017E-06	1.8988E-06	-3.0723E-06
13061	157)	-1.2390E-05	1.3911E-04	4.1647E-05	5.2317E-06	1.9042E-06	-3.0798E-06
1200	163)	3.8980E-04	1.4015E-06	4.0160E-04	8.4008E-06	-4.4056E-06	-1.1538E-05
15010	169)	1.8480E-06	5.8976E-08	1.1054E-04	1.2645E-05	-1.3096E-05	-1.5513E-05
15050	175)	-6.3509E-04	-8.5150E-07	-4.0274E-04	1.4179E-05	-1.4863E-05	-1.7482E-05
1226	181)	-9.4363E-04	1.1547E-04	-7.5186E-04	1.4184E-05	-1.4872E-05	-1.7488E-05

Eigenvalue = 1.9494E+01 REAL EIGENVECTOR NO. 22
Radian = 4.4152E+00

NODE	ROW	TX	TY	TZ	RX	RY	RZ
1126	1)	2.2233E-04	-1.6756E-04	-2.7700E-04	-5.3058E-06	-2.9255E-07	-3.6857E-06
15040	7)	1.2920E-04	-1.2406E-04	-1.4639E-04	-5.3045E-06	-2.9296E-07	-3.6847E-06
15000	13)	-6.2133E-06	-1.2466E-04	4.7528E-05	-4.7941E-06	-3.6564E-07	-3.3191E-06
1100	19)	-9.2633E-05	-1.2455E-04	1.6426E-04	-3.5866E-06	-5.4695E-07	-2.7298E-06
74	25)	-1.2134E-04	-1.2385E-04	1.9485E-04	-1.4606E-07	-5.4923E-07	-7.3792E-07
64	31)	-1.3951E-04	-1.2817E-04	1.6675E-04	-2.6047E-03	-7.7761E-05	-3.4469E-03
55	37)	-9.8517E-05	-1.0673E-04	1.0656E-04	-3.8060E-04	9.8648E-06	2.3933E-04
56	43)	-1.1666E-04	-1.5576E-04	1.0622E-04	3.6796E-03	1.4492E-04	5.2847E-03
51	49)	-5.3157E-05	-1.0332E-04	4.3335E-05	-3.3704E-04	3.6828E-04	-1.0836E-04
52	55)	-5.5044E-05	-1.4176E-04	3.7746E-05	-1.9912E-04	-9.1389E-06	-7.9519E-05
13032	61)	7.3019E-05	-4.2659E-05	-6.9529E-05	-2.2597E-07	8.8794E-07	-6.1642E-06
44	67)	7.4070E-06	-1.3127E-04	-5.0561E-05	1.7302E-02	6.6716E-04	2.4532E-02
16020	73)	-1.6632E-06	-9.4952E-05	-7.0334E-05	-1.1494E-06	1.0041E-06	-1.4761E-06
13008	79)	-4.6028E-05	-4.3311E-05	-6.3498E-05	-3.3561E-07	7.6521E-07	-6.1455E-06
32	85)	-1.1722E-04	-3.7720E-05	1.0038E-04	9.7017E-05	3.8451E-05	4.8596E-04
23	91)	-2.7577E-04	-1.6256E-04	3.9205E-04	-1.9385E-05	1.5085E-05	-3.4065E-05
24	97)	-2.2268E-04	-4.2492E-05	3.9935E-04	1.4814E-04	-7.6308E-05	-6.9860E-04
16030	103)	-3.0852E-04	-1.1448E-04	5.9555E-04	-6.5137E-06	2.5576E-06	-1.4664E-06
12	109)	-3.3053E-04	-9.2534E-05	7.5847E-04	4.2486E-04	-1.7164E-05	2.2090E-04
1	115)	-3.2241E-04	-1.3437E-04	8.4912E-04	3.2007E-07	-1.5529E-06	1.7333E-06
13051	121)	7.3011E-05	-2.1763E-04	-9.3996E-05	-3.7016E-07	8.3907E-07	-6.1190E-06
13049	127)	1.3454E-05	-1.8093E-04	-8.5176E-05	-4.0227E-07	8.2536E-07	-6.1006E-06
13000	133)	-4.6003E-05	-2.1754E-04	-8.6066E-05	-4.1007E-07	8.1164E-07	-6.0985E-06
13011	139)	-4.6149E-05	2.0264E-04	-3.2585E-05	-1.6286E-07	7.9134E-07	-6.1338E-06
13050	145)	1.3540E-05	1.6585E-04	-3.8710E-05	-1.1929E-07	8.1644E-07	-6.1129E-06
13039	151)	7.3108E-05	2.0250E-04	-3.4605E-05	-7.4354E-08	8.4154E-07	-6.1091E-06
13061	157)	5.7964E-05	1.6479E-04	-3.9670E-05	-5.0471E-08	8.3469E-07	-6.1242E-06
1200	163)	-2.4381E-04	-1.3525E-04	7.2195E-04	1.5270E-05	-1.9902E-06	7.7852E-06
15010	169)	-1.2845E-06	-1.3318E-04	2.1495E-04	2.1049E-05	-6.6526E-06	8.8999E-06
15050	175)	3.6331E-04	-1.2976E-04	-6.3786E-04	2.3325E-05	-7.3242E-06	9.8428E-06
1226	181)	6.6583E-04	6.1666E-05	-1.2122E-03	2.3332E-05	-7.3260E-06	9.8454E-06

Eigenvalue = 1.9643E+01 REAL EIGENVECTOR NO. 23
Radian = 4.4321E+00

NODE	ROW	TX	TY	TZ	RX	RY	RZ
1126	1)	1.6355E-04	-3.2731E-05	-7.5268E-04	-1.4200E-05	-6.5711E-06	-1.9563E-06
15040	7)	6.1462E-05	8.3695E-05	-4.0314E-04	-1.4196E-05	-6.5713E-06	-1.9558E-06
15000	13)	-1.3256E-05	8.1529E-05	1.1559E-04	-1.2762E-05	-7.2163E-06	-1.8293E-06
1100	19)	-5.9131E-05	7.9537E-05	4.3254E-04	-9.7281E-06	-5.9260E-06	-1.3182E-06
74	25)	-7.2255E-05	7.9033E-05	5.1405E-04	-1.9227E-07	-5.2942E-06	-2.7716E-07
64	31)	-1.0201E-04	5.2332E-05	4.2495E-04	-4.7234E-05	4.1581E-06	4.2803E-05
55	37)	-2.6188E-05	1.1633E-04	2.8770E-04	2.4492E-06	-9.8339E-07	-4.9619E-06
56	43)	-6.7693E-05	3.6731E-05	2.8674E-04	2.1808E-05	-1.4719E-05	-1.1092E-04
51	49)	-1.7233E-05	1.1932E-04	1.9921E-04	2.2077E-06	-8.4659E-06	1.6974E-06
52	55)	-4.6005E-05	3.5200E-05	1.9777E-04	4.2024E-05	-4.5402E-06	-6.5384E-06
13032	61)	2.2886E-06	-1.9772E-05	-3.1114E-06	5.1950E-06	1.9511E-07	2.0851E-06
44	67)	-1.3857E-06	4.5270E-05	2.2422E-05	-1.5598E-04	-3.4415E-05	-5.4293E-04
16020	73)	2.4637E-05	9.0260E-05	-6.3739E-05	3.6774E-06	1.0049E-07	2.4779E-07
13008	79)	4.2672E-05	-1.9831E-05	-1.0442E-04	5.1750E-06	2.1635E-07	2.0885E-06
32	85)	3.0484E-05	1.1178E-04	-1.4817E-04	1.0991E-02	-6.0324E-05	1.0339E-02
23	91)	-1.1742E-04	7.5028E-05	-2.9459E-05	2.1965E-03	-6.1840E-05	-7.7335E-04
24	97)	-8.8718E-05	2.2613E-04	-2.5061E-05	-1.9954E-02	2.7829E-05	-1.8513E-02
16030	103)	-3.2957E-04	1.1456E-04	2.5638E-04	-6.3395E-06	-6.0817E-07	-3.4479E-06
12	109)	-4.1949E-04	1.3308E-04	4.0769E-04	2.4478E-04	-1.4801E-06	2.4417E-04
1	115)	-4.3225E-04	7.9065E-05	5.1394E-04	-9.5540E-07	-6.2698E-07	1.3405E-06
13051	121)	2.2727E-06	3.9512E-05	-8.7926E-06	5.2089E-06	2.0239E-07	2.0755E-06
13049	127)	2.2489E-05	2.7063E-05	-5.8364E-05	5.2078E-06	2.0333E-07	2.0725E-06
13000	133)	4.2709E-05	3.9525E-05	-1.1034E-04	5.2012E-06	2.0427E-07	2.0765E-06
13011	139)	4.2615E-05	-1.0280E-04	-9.5686E-05	5.1519E-06	2.1243E-07	2.0673E-06
13050	145)	2.2458E-05	-9.0402E-05	-4.6699E-05	5.1586E-06	2.0896E-07	2.0679E-06
13039	151)	2.2831E-06	-1.0283E-04	4.8685E-06	5.1666E-06	2.0549E-07	2.0710E-06
13061	157)	-1.4424E-06	3.2041E-06	3.6370E-06	5.1769E-06	2.0609E-07	2.0761E-06
1200	163)	-3.2914E-04	7.9425E-05	4.3726E-04	1.0295E-05	-7.2196E-07	1.1087E-05
15010	169)	3.2534E-05	8.4203E-05	8.8438E-05	1.4221E-05	-2.1891E-06	1.3620E-05
15050	175)	5.9427E-04	8.8840E-05	-4.9197E-04	1.5775E-05	-2.1602E-06	1.5231E-05
1226	181)	9.8712E-04	2.1834E-04	-8.8048E-04	1.5780E-05	-2.1589E-06	1.5236E-05

Eigenvalue = 2.0005E+01 REAL EIGENVECTOR NO. 24
Radian = 4.4727E+00

NODE	ROW	TX	TY	TZ	RX	RY	RZ
1126	1)	-7.1743E-05	-3.1328E-05	-5.5190E-04	-1.0054E-05	-1.2390E-05	2.3669E-06
15040	7)	-1.1511E-04	5.1116E-05	-3.0442E-04	-1.0051E-05	-1.2388E-05	2.3661E-06
15000	13)	-3.0553E-05	5.0148E-05	6.1878E-05	-8.9772E-06	-1.3082E-05	2.0195E-06
1100	19)	3.0162E-05	4.9345E-05	2.9021E-04	-7.1186E-06	-9.2830E-06	2.0537E-06
74	25)	4.8143E-05	4.9066E-05	3.4749E-04	1.8385E-07	-8.0041E-06	7.6492E-08
64	31)	2.3610E-05	3.2653E-05	2.7601E-04	-2.2376E-03	3.4908E-04	1.5385E-03
55	37)	3.5493E-05	9.8506E-05	1.8227E-04	-5.6703E-04	1.8843E-04	-2.2596E-04
56	43)	3.0205E-05	2.3610E-05	1.8146E-04	6.2846E-03	-1.0162E-03	-4.5730E-03
51	49)	-5.2591E-06	1.0141E-04	7.8876E-05	-7.0928E-04	-1.8842E-04	-9.0044E-05
52	55)	-6.4508E-06	2.7387E-05	7.1455E-05	2.1472E-03	-2.1439E-04	-1.6794E-03
13032	61)	-2.5562E-05	3.4358E-06	-1.0449E-04	1.8890E-06	2.5734E-06	2.5077E-06
44	67)	-2.6592E-05	3.3960E-05	-3.2145E-05	2.4295E-02	-3.6635E-03	-1.7129E-02
16020	73)	-5.4553E-05	5.6541E-05	-1.3026E-04	2.0358E-08	1.3668E-06	1.6477E-07
13008	79)	2.2984E-05	3.3877E-06	-1.4088E-04	1.8041E-06	2.6197E-06	2.5142E-06
32	85)	9.9091E-05	1.1294E-04	9.9880E-05	2.0279E-06	3.6971E-06	-3.5782E-05
23	91)	7.2895E-05	-7.8225E-05	5.7458E-04	-4.7556E-05	1.6290E-05	2.2587E-06
24	97)	2.4237E-04	1.2705E-04	5.8837E-04	3.4001E-04	-2.2140E-05	-1.2189E-06
16030	103)	2.4381E-04	2.2719E-05	9.2104E-04	-1.1879E-05	9.7300E-06	3.3979E-06
12	109)	3.6563E-04	9.7353E-05	1.2029E-03	2.1646E-04	-1.4244E-05	6.1184E-06
1	115)	3.3288E-04	3.8383E-05	1.3477E-03	-4.8261E-07	-1.3810E-06	-8.8690E-07
13051	121)	-2.5533E-05	7.4692E-05	-1.7802E-04	1.9098E-06	2.5876E-06	2.4948E-06
13049	127)	-1.2499E-06	5.9766E-05	-1.8106E-04	1.8969E-06	2.5895E-06	2.4884E-06
13000	133)	2.3027E-05	7.4770E-05	-2.1498E-04	1.8690E-06	2.5914E-06	2.4935E-06
13011	139)	2.2943E-05	-9.6558E-05	-3.5644E-05	1.7758E-06	2.6285E-06	2.4908E-06
13050	145)	-1.3462E-06	-8.1624E-05	-3.4011E-05	1.7944E-06	2.6226E-06	2.4922E-06
13039	151)	-2.5663E-05	-9.6612E-05	-7.2366E-07	1.8131E-06	2.6167E-06	2.4964E-06
13061	157)	-7.3205E-05	-4.8872E-05	-1.6431E-05	1.8093E-06	2.6328E-06	2.5027E-06
1200	163)	2.7320E-04	3.8711E-05	1.1583E-03	2.3730E-05	-2.3697E-06	-6.3753E-06
15010	169)	5.3889E-05	4.0533E-05	3.6119E-04	3.3576E-05	-1.3724E-05	-9.3609E-06
15050	175)	-3.2891E-04	4.3415E-05	-1.0019E-03	3.7467E-05	-1.6357E-05	-1.0706E-05
1226	181)	-4.5827E-04	3.5086E-04	-1.9244E-03	3.7478E-05	-1.6367E-05	-1.0711E-05

Eigenvalue = 2.1410E+01 REAL EIGENVECTOR NO. 25
Radian = 4.6271E+00

NODE	ROW	TX	TY	TZ	RX	RY	RZ
1126	1)	-5.8712E-04	-5.8502E-04	-3.7366E-03	-7.2402E-05	-3.9844E-05	1.4180E-05
15040	7)	-5.6496E-04	8.7058E-06	-1.9543E-03	-7.2382E-05	-3.9844E-05	1.4175E-05
15000	13)	-6.2842E-05	2.6708E-06	6.7341E-04	-6.4364E-05	-4.4872E-05	1.2012E-05
1100	19)	2.6814E-04	-2.2891E-07	2.2490E-03	-4.8156E-05	-3.6369E-05	1.0624E-05
74	25)	3.5853E-04	-1.1018E-07	2.6200E-03	2.8954E-06	-3.1974E-05	1.6392E-07
64	31)	1.4709E-04	-1.2005E-04	1.9938E-03	-2.8904E-03	5.0789E-04	2.4922E-03
55	37)	3.3547E-04	3.1899E-04	1.1458E-03	-1.2208E-03	5.4486E-04	-6.4153E-04
56	43)	5.8395E-05	-1.4319E-04	1.1335E-03	1.5474E-02	-2.9617E-03	-1.3817E-02
51	49)	1.6259E-04	3.3448E-04	5.2123E-04	-2.5705E-03	-3.7298E-04	-5.9226E-04
52	55)	-1.4773E-04	-1.1984E-04	4.8153E-04	1.5845E-02	-2.5460E-03	-1.4116E-02
13032	61)	2.5478E-05	-3.7654E-05	-2.8566E-04	4.4634E-06	7.0853E-06	-1.1510E-06
44	67)	-1.1810E-04	-1.6264E-05	-2.0878E-04	-6.2009E-03	1.0201E-03	5.1215E-03
16020	73)	-1.3012E-04	5.9769E-05	-3.1883E-04	3.9697E-06	6.6938E-06	3.7454E-07
13008	79)	3.3111E-06	-3.7763E-05	-3.7205E-04	4.3640E-06	7.0954E-06	-1.1380E-06
32	85)	5.4335E-05	1.3747E-04	5.8807E-06	5.5172E-05	7.4289E-06	-1.7652E-05
23	91)	-6.6828E-05	-1.6826E-04	7.5219E-04	-4.0081E-05	2.1151E-05	3.1373E-06
24	97)	2.2764E-04	1.7241E-04	7.7308E-04	1.7759E-04	-2.6513E-06	-1.7267E-05
16030	103)	1.9560E-04	-5.2280E-06	1.3390E-03	-2.0492E-05	1.6249E-05	4.8757E-06
12	109)	3.8121E-04	1.2368E-04	1.8353E-03	1.4172E-04	-6.3016E-06	-2.7119E-06
1	115)	3.4749E-04	1.2505E-05	2.1468E-03	-2.8904E-06	-3.1178E-06	-1.9216E-07
13051	121)	2.5519E-05	-7.0038E-05	-4.8728E-04	4.4485E-06	7.0765E-06	-1.1306E-06
13049	127)	1.4475E-05	-6.3208E-05	-4.8811E-04	4.4294E-06	7.0719E-06	-1.1340E-06
13000	133)	3.4234E-06	-6.9953E-05	-5.7356E-04	4.3981E-06	7.0673E-06	-1.1320E-06
13011	139)	3.1084E-06	8.2729E-06	-8.6902E-05	4.3980E-06	7.1388E-06	-1.1491E-06
13050	145)	1.4260E-05	1.3799E-06	-8.6744E-05	4.4213E-06	7.1482E-06	-1.1400E-06
13039	151)	2.5369E-05	8.2222E-06	-5.5919E-07	4.4490E-06	7.1575E-06	-1.1401E-06
13061	157)	-1.0452E-04	8.2151E-05	-4.3523E-05	4.4714E-06	7.1892E-06	-1.1432E-06
1200	163)	2.9975E-04	1.2686E-05	1.8770E-03	3.6154E-05	-5.1156E-06	-5.6518E-06
15010	169)	8.9747E-05	1.5534E-05	6.4926E-04	5.2516E-05	-2.4963E-05	-9.7554E-06
15050	175)	-3.1040E-04	2.0703E-05	-1.4897E-03	5.8944E-05	-2.9006E-05	-1.1356E-05
1226	181)	-3.5195E-04	5.0441E-04	-2.9411E-03	5.8962E-05	-2.9021E-05	-1.1362E-05

Eigenvalue = 2.1523E+01 REAL EIGENVECTOR NO. 26
Radian = 4.6393E+00

NODE	ROW	TX	TY	TZ	RX	RY	RZ
1126	1)	4.0772E-03	-1.2604E-03	-5.9280E-03	-1.1594E-04	-2.6716E-05	-6.5687E-05
15040	7)	2.2407E-03	-3.0994E-04	-3.0739E-03	-1.1590E-04	-2.6722E-05	-6.5668E-05
15000	13)	-1.7739E-04	-3.3163E-04	1.1538E-03	-1.0362E-04	-2.9336E-05	-5.8654E-05
1100	19)	-1.6910E-03	-3.4622E-04	3.6709E-03	-7.6145E-05	-2.5512E-05	-4.6242E-05
74	25)	-2.1276E-03	-3.4471E-04	4.2579E-03	4.3326E-06	-2.3248E-05	-6.4994E-06
64	31)	-2.2005E-03	-6.4658E-04	3.3733E-03	-2.6530E-03	-4.9458E-05	-2.9512E-03
55	37)	-1.3067E-03	-5.7809E-05	1.9738E-03	-1.0446E-03	-4.1200E-05	7.4905E-04
56	43)	-1.5493E-03	-8.1848E-04	1.9661E-03	1.3754E-02	2.1518E-04	1.6005E-02
51	49)	-8.2455E-04	-3.8556E-05	1.0592E-03	-2.4880E-03	1.3499E-03	3.1964E-04
52	55)	-9.3446E-04	-7.4067E-04	1.0223E-03	1.3868E-02	1.8152E-04	1.6109E-02
13032	61)	2.0391E-04	-1.5537E-04	-4.2608E-04	8.6962E-06	7.6786E-06	-1.7000E-05
44	67)	-6.5372E-05	-3.6930E-04	-3.3640E-04	-3.6544E-03	-2.0263E-05	-3.8624E-03
16020	73)	-1.5967E-04	-1.7174E-04	-4.9631E-04	8.0639E-06	6.5650E-06	6.3104E-06
13008	79)	-1.2468E-04	-1.5637E-04	-5.9118E-04	8.4066E-06	7.2980E-06	-1.6971E-05
32	85)	1.5095E-04	-1.2967E-04	1.4595E-05	8.0293E-05	1.0771E-05	-6.1922E-05
23	91)	1.4122E-04	-6.1476E-04	1.2174E-03	-6.3613E-05	3.9199E-05	8.3543E-06
24	97)	6.7265E-04	-6.6961E-05	1.2535E-03	2.7430E-04	-4.1571E-06	-6.3712E-05
16030	103)	7.3324E-04	-3.4809E-04	2.1734E-03	-3.3414E-05	2.9989E-05	1.2792E-05
12	109)	1.1618E-03	-1.2403E-04	2.9804E-03	2.2033E-04	-8.7430E-06	-2.3467E-05
1	115)	1.1036E-03	-2.9151E-04	3.4716E-03	-4.8393E-06	-3.7198E-06	-1.6884E-06
13051	121)	2.0385E-04	-6.3748E-04	-6.4198E-04	8.2682E-06	7.5151E-06	-1.6861E-05
13049	127)	3.9635E-05	-5.3627E-04	-6.7696E-04	8.1689E-06	7.4668E-06	-1.6829E-05
13000	133)	-1.2443E-04	-6.3722E-04	-8.0090E-04	8.1352E-06	7.4186E-06	-1.6831E-05
13011	139)	-1.2529E-04	5.2223E-04	-2.9730E-04	8.9832E-06	7.4075E-06	-1.6924E-05
13050	145)	3.9499E-05	4.2076E-04	-2.5375E-04	9.0725E-06	7.5049E-06	-1.6886E-05
13039	151)	2.0414E-04	5.2219E-04	-1.1914E-04	9.1854E-06	7.6023E-06	-1.6895E-05
13061	157)	6.6527E-05	5.8839E-04	-1.6483E-04	9.2993E-06	7.6074E-06	-1.6941E-05
1200	163)	9.1571E-04	-2.9313E-04	3.0407E-03	5.8009E-05	-7.0624E-06	-2.1168E-05
15010	169)	1.7646E-04	-2.9404E-04	1.0716E-03	8.4718E-05	-4.1541E-05	-3.1242E-05
15050	175)	-1.1118E-03	-2.8980E-04	-2.3775E-03	9.5245E-05	-4.9190E-05	-3.5914E-05
1226	181)	-1.5925E-03	4.9174E-04	-4.7228E-03	9.5274E-05	-4.9219E-05	-3.5930E-05

Eigenvalue = 2.2636+01 REAL EIGENVECTOR NO. 27
Radian = 4.7577+00

NODE	ROW	TX	TY	TZ	RX	RY	RZ
1126	1)	-1.3032E-02	6.5709E-03	3.4344E-02	6.8998E-04	2.1381E-04	2.0040E-04
15040	7)	-6.3438E-03	9.1365E-04	1.7358E-02	6.8978E-04	2.1384E-04	2.0034E-04
15000	13)	1.0896E-03	1.0176E-03	-7.6945E-03	6.1258E-04	2.4218E-04	1.8040E-04
1100	19)	5.6598E-03	1.0773E-03	-2.2459E-02	4.4668E-04	2.0526E-04	1.3797E-04
74	25)	6.9752E-03	1.0725E-03	-2.5788E-02	-3.8083E-05	1.8331E-04	2.1609E-05
64	31)	7.8258E-03	2.6672E-03	-1.9787E-02	9.5292E-05	1.3696E-04	-6.8952E-05
55	37)	3.9631E-03	-9.9139E-04	-1.1456E-02	-5.5852E-04	1.7322E-04	1.8527E-05
56	43)	5.5330E-03	3.0558E-03	-1.1328E-02	3.8738E-03	-1.7091E-04	1.3582E-03
51	49)	3.0162E-03	-1.0274E-03	-6.8154E-03	-1.0173E-03	2.9503E-04	-6.8574E-05
52	55)	4.0283E-03	2.8295E-03	-6.6793E-03	3.8806E-03	-1.5940E-04	1.3809E-03
13032	61)	-8.0465E-04	1.3124E-03	2.2969E-03	-1.1098E-04	-5.7064E-05	9.0979E-05
44	67)	8.5039E-04	1.5068E-03	1.4642E-03	3.8305E-05	-5.7627E-05	-2.2631E-04
16020	73)	1.4532E-03	2.0363E-04	3.3531E-03	-7.8849E-05	-4.9151E-05	-2.9583E-05
13008	79)	9.5398E-04	1.3178E-03	4.4339E-03	-1.0913E-04	-5.4748E-05	9.0819E-05
32	85)	-1.3456E-03	1.0965E-04	1.1515E-03	-3.7148E-04	-1.0298E-04	3.6942E-04
23	91)	-2.0456E-03	3.0837E-03	-6.2348E-03	3.5130E-04	-2.8034E-04	-8.4534E-05
24	97)	-5.9464E-03	-4.0858E-04	-6.4605E-03	-1.1630E-03	-4.4258E-05	4.7931E-04
16030	103)	-6.9984E-03	1.3463E-03	-1.2423E-02	2.2130E-04	-2.2304E-04	-1.1609E-04
12	109)	-1.0735E-02	-2.8603E-04	-1.7762E-02	-9.8487E-04	8.0387E-06	2.3857E-04
1	115)	-1.0559E-02	7.1132E-04	-2.1200E-02	4.7923E-05	1.5202E-05	1.3921E-05
13051	121)	-8.0410E-04	3.8909E-03	3.9046E-03	-1.0836E-04	-5.6038E-05	9.0182E-05
13049	127)	7.4299E-05	3.3495E-03	4.6216E-03	-1.0774E-04	-5.5729E-05	9.0028E-05
13000	133)	9.5192E-04	3.8893E-03	6.0031E-03	-1.0750E-04	-5.5420E-05	9.0021E-05
13011	139)	9.5832E-04	-2.3178E-03	2.2270E-03	-1.1273E-04	-5.5608E-05	9.0680E-05
13050	145)	7.5588E-05	-1.7741E-03	1.4587E-03	-1.1332E-04	-5.6275E-05	9.0445E-05
13039	151)	-8.0638E-04	-2.3177E-03	8.6916E-06	-1.1406E-04	-5.6942E-05	9.0523E-05
13061	157)	2.2587E-04	-3.8492E-03	3.5051E-04	-1.1496E-04	-5.7106E-05	9.0781E-05
1200	163)	-8.7810E-03	7.1332E-04	-1.8829E-02	-3.4172E-04	3.9784E-05	2.0254E-04
15010	169)	-1.8224E-03	7.2690E-04	-7.0894E-03	-5.1329E-04	2.8523E-04	2.8948E-04
15050	175)	1.0149E-02	7.1316E-04	1.3868E-02	-5.8088E-04	3.4113E-04	3.3293E-04
1226	181)	1.5548E-02	-4.0531E-03	2.8171E-02	-5.8107E-04	3.4135E-04	3.3307E-04

Eigenvalue = 2.4334+01 REAL EIGENVECTOR NO. 28
Radian = 4.9330

NODE	ROW	TX	TY	TZ	RX	RY	RZ
1126	1)	-8.1553E-03	1.6081E-03	-1.2643E-02	-2.6364E-04	-1.2141E-04	1.6259E-04
15040	7)	-5.1490E-03	3.7701E-03	-6.1531E-03	-2.6356E-04	-1.2142E-04	1.6253E-04
15000	13)	6.6387E-04	3.7468E-03	3.3381E-03	-2.3071E-04	-1.4898E-04	1.3972E-04
1100	19)	4.2574E-03	3.7180E-03	8.8538E-03	-1.6602E-04	-1.2959E-04	1.1257E-04
74	25)	5.2861E-03	3.6921E-03	1.0014E-02	2.2962E-05	-1.1337E-04	1.1923E-05
64	31)	4.2475E-03	3.2004E-03	7.1569E-03	-1.2127E-04	-9.1630E-05	2.1627E-06
55	37)	4.4419E-03	4.7116E-03	3.9121E-03	1.3686E-04	-9.3839E-05	-2.9946E-05
56	43)	3.2450E-03	3.1940E-03	3.8584E-03	-5.9274E-04	1.5864E-05	2.1674E-04
51	49)	3.5008E-03	4.6639E-03	2.2061E-03	2.1331E-04	-6.0117E-05	-2.7290E-05
52	55)	2.5743E-03	3.2746E-03	2.1432E-03	-5.8866E-04	1.9271E-05	2.3680E-04
13032	61)	-2.4947E-04	8.7850E-04	-2.7234E-04	4.3243E-05	-2.7901E-05	1.8568E-04
44	67)	1.1331E-03	3.4628E-03	1.6220E-04	-1.7133E-04	-1.4803E-05	-2.3505E-04
16020	73)	2.5914E-03	3.8121E-03	-1.0472E-03	2.2137E-05	-2.5591E-05	-6.0523E-05
13008	79)	3.3411E-03	8.8127E-04	-1.1473E-03	4.3815E-05	-2.3599E-05	1.8576E-04
32	85)	-2.5253E-03	6.5755E-03	-1.7358E-03	1.8039E-04	-7.8255E-05	6.7597E-04
23	91)	-1.1612E-02	5.3245E-03	1.6204E-03	-1.5743E-04	-2.6135E-04	-2.6061E-04
24	97)	-1.4726E-02	6.9430E-03	1.7050E-03	4.1602E-04	-7.5006E-05	1.0685E-03
16030	103)	-2.1743E-02	5.8065E-03	4.5327E-03	-8.9670E-05	-1.8556E-04	-3.1422E-04
12	109)	-2.9924E-02	5.5167E-03	7.5015E-03	3.9540E-04	-7.5628E-05	7.0181E-04
1	115)	-3.1947E-02	3.4584E-03	1.0901E-02	-2.7609E-05	-2.3013E-05	3.8254E-05
13051	121)	-2.4857E-04	6.1471E-03	4.9351E-04	4.7407E-05	-2.6185E-05	1.8431E-04
13049	127)	1.5464E-03	5.0413E-03	-1.2955E-04	4.8020E-05	-2.5758E-05	1.8397E-04
13000	133)	3.3405E-03	6.1464E-03	-4.4504E-04	4.7721E-05	-2.5330E-05	1.8416E-04
13011	139)	3.3429E-03	-6.5244E-03	-2.1044E-03	3.8018E-05	-2.4861E-05	1.8459E-04
13050	145)	1.5446E-03	-5.4178E-03	-1.5861E-03	3.7691E-05	-2.6007E-05	1.8438E-04
13039	151)	-2.5402E-04	-6.5265E-03	-1.3835E-03	3.7271E-05	-2.7152E-05	1.8465E-04
13061	157)	2.3854E-04	-4.7536E-03	-1.2212E-03	3.6494E-05	-2.7260E-05	1.8522E-04
1200	163)	-2.6281E-02	3.4752E-03	9.5655E-03	1.9256E-04	-8.1731E-06	6.5100E-04
15010	169)	-4.6769E-03	3.6626E-03	3.1079E-03	2.5827E-04	1.0448E-04	8.5012E-04
15050	175)	3.0743E-02	3.8689E-03	-7.5519E-03	2.8681E-04	1.5282E-04	9.7469E-04
1226	181)	5.3495E-02	6.2253E-03	-1.4618E-02	2.8686E-04	1.5307E-04	9.7506E-04

Eigenvalue = 2.8780+01 REAL EIGENVECTOR NO. 29
Radian = 5.3647+00

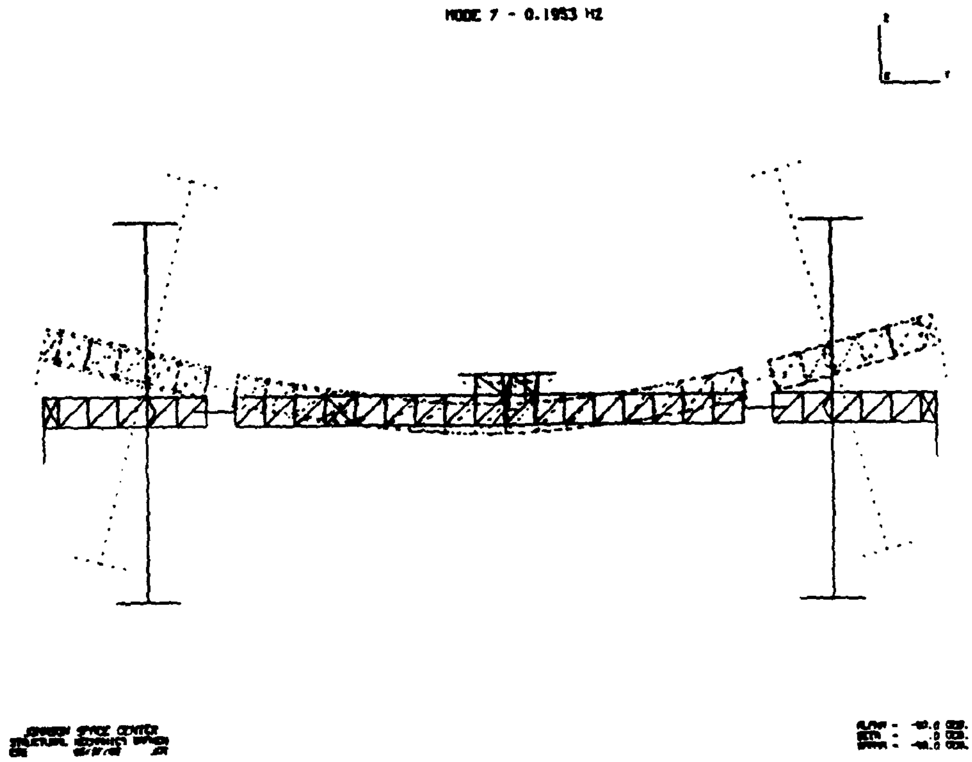
NODE	ROW	TX	TY	TZ	RX	RY	RZ
1126	1)	-5.5986E-02	4.7896E-03	1.7681E-03	3.7553E-05	-1.9520E-04	1.0811E-03
15040	7)	-3.0969E-02	4.4847E-03	8.4062E-04	3.7543E-05	-1.9517E-04	1.0807E-03
15000	13)	7.8412E-03	4.6431E-03	-8.0867E-04	4.0980E-05	-2.7670E-04	9.1949E-04
1100	19)	3.0978E-02	4.7252E-03	-1.6610E-03	1.9684E-05	-2.3269E-04	6.9897E-04
74	25)	3.6487E-02	4.6978E-03	-1.7671E-03	-4.9929E-06	-1.8989E-04	-2.7497E-05
64	31)	2.9086E-02	6.6547E-03	-2.1111E-03	2.3086E-05	-1.4185E-04	2.1803E-04
55	37)	1.8472E-02	6.6818E-03	-6.8182E-04	-4.1356E-05	-1.1836E-04	-3.2494E-04
56	43)	1.6821E-02	6.8330E-03	-5.6750E-04	6.0525E-05	1.2468E-05	8.7400E-04
51	49)	1.0988E-02	6.5329E-03	6.1130E-05	-6.1706E-05	5.0098E-05	-3.6478E-04
52	55)	9.9416E-03	6.3141E-03	1.5400E-04	6.8538E-05	3.3658E-05	8.8283E-04
13032	61)	-2.4606E-03	-1.1798E-03	1.7490E-04	1.4080E-04	6.4957E-05	6.8023E-05
44	67)	-1.6693E-03	4.0151E-03	1.4267E-03	-1.9672E-04	1.0913E-04	7.6999E-05
16020	73)	-2.8077E-03	3.3200E-03	-1.2968E-03	6.1812E-05	6.8384E-05	-9.0985E-05
13008	79)	-1.1604E-03	-1.1727E-03	-2.5901E-03	1.4126E-04	6.7421E-05	6.7902E-05
32	85)	-4.6216E-04	3.6079E-03	-2.2776E-03	3.5295E-05	1.1151E-04	-6.4676E-05
23	91)	6.6938E-04	2.5810E-03	-7.9055E-05	-1.0096E-04	1.8683E-04	9.9676E-05
24	97)	3.3401E-03	3.8290E-03	-2.4687E-05	1.2978E-04	1.0632E-04	-2.0435E-04
16030	103)	5.2443E-03	3.2394E-03	2.2370E-03	-9.2591E-05	1.5916E-04	1.3053E-04
12	109)	9.3030E-03	4.1928E-03	4.3802E-03	1.3160E-04	5.8786E-05	-1.7154E-04
1	115)	1.0530E-02	4.2750E-03	5.8347E-03	-4.4951E-05	1.8672E-05	1.4143E-05
13051	121)	-2.4604E-03	7.4558E-04	-1.6879E-03	1.4320E-04	6.5732E-05	6.7081E-05
13049	127)	-1.8088E-03	3.4372E-04	-2.6917E-03	1.4353E-04	6.5940E-05	6.6674E-05
13000	133)	-1.1585E-03	7.4523E-04	-4.4872E-03	1.4327E-04	6.6148E-05	6.6815E-05
13011	139)	-1.1605E-03	-3.8663E-03	1.3091E-04	1.3845E-04	6.8125E-05	6.6886E-05
13050	145)	-1.8118E-03	-3.4652E-03	1.0714E-03	1.3830E-04	6.7987E-05	6.6749E-05
13039	151)	-2.4625E-03	-3.8658E-03	2.8257E-03	1.3802E-04	6.7849E-05	6.6729E-05
13061	157)	-3.7019E-03	-9.6630E-04	2.4200E-03	1.3820E-04	6.8837E-05	6.6972E-05
1200	163)	9.1549E-03	4.3161E-03	5.6057E-03	7.5705E-05	1.1144E-06	-1.8351E-04
15010	169)	2.8920E-03	4.3385E-03	2.6858E-03	1.4133E-04	-1.4973E-04	-2.6437E-04
15050	175)	-8.2078E-03	4.3344E-03	-3.2024E-03	1.6665E-04	-1.8613E-04	-3.1124E-04
1226	181)	-1.4346E-02	5.7017E-03	-7.3064E-03	1.6673E-04	-1.8629E-04	-3.1138E-04

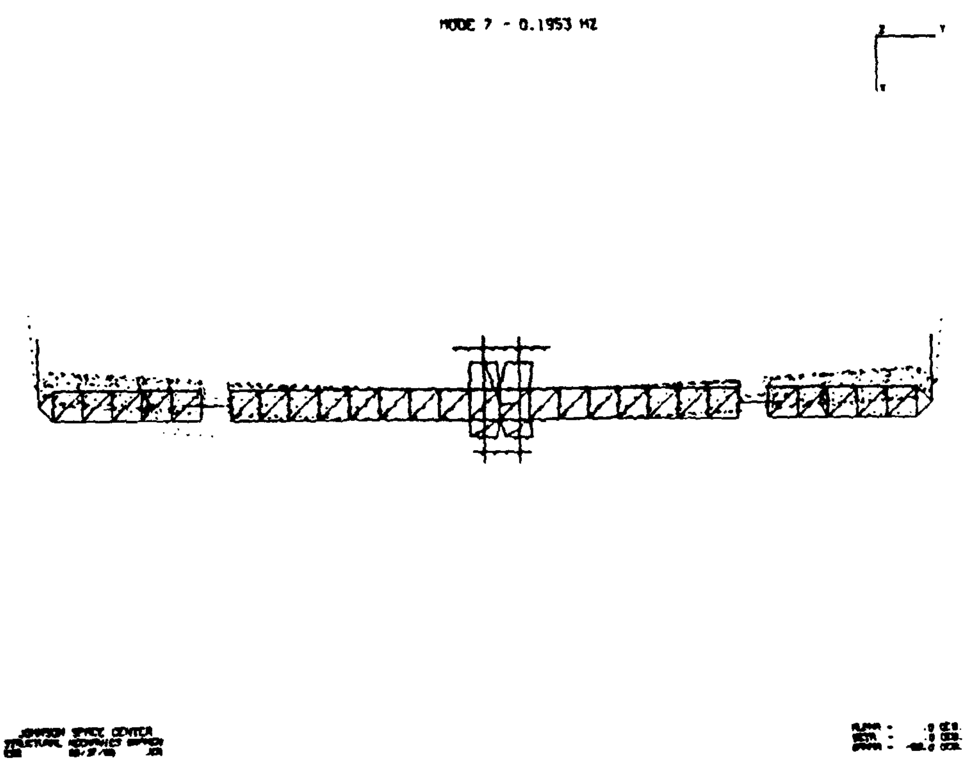
Eigenvalue = 3.7729E+01 REAL EIGENVECTOR NO. 30
Radian = 6.1424E+00

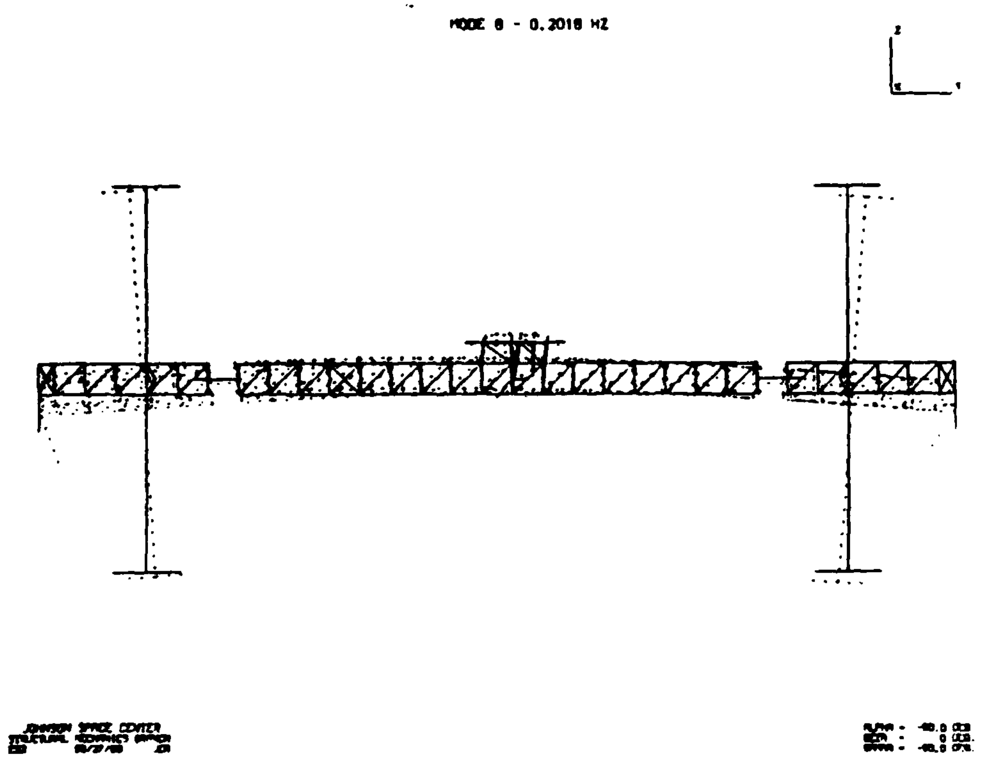
NODE	ROW	TX	TY	TZ	RX	RY	RZ
1126	1)	-1.5378E-02	-1.0926E-02	-2.2806E-02	-5.7678E-04	-4.3448E-05	3.3435E-04
15040	7)	-7.5023E-03	-6.1948E-03	-8.6075E-03	-5.7656E-04	-4.3529E-05	3.3419E-04
15000	13)	4.1436E-03	-6.1569E-03	1.1417E-02	-4.7429E-04	-1.2790E-04	2.6700E-04
1100	19)	1.0554E-02	-6.0162E-03	2.1063E-02	-2.7302E-04	-1.8339E-04	1.8341E-04
74	25)	1.1570E-02	-5.9417E-03	2.1577E-02	1.9362E-04	-1.6743E-04	-5.5160E-05
64	31)	6.2881E-03	-6.8972E-03	9.1185E-03	-1.4418E-04	-2.0115E-04	6.1192E-05
55	37)	4.8218E-03	-2.3902E-03	-2.0355E-03	2.5243E-04	-2.1525E-04	-1.3841E-04
56	43)	1.4859E-03	-5.8290E-03	-2.3858E-03	-2.1164E-04	-1.2521E-04	1.2355E-04
51	49)	2.1224E-03	-3.1575E-03	-6.0085E-03	2.3915E-04	-1.3290E-04	-1.2378E-04
52	55)	-4.3251E-04	-5.0033E-03	-6.3325E-03	-2.2897E-04	-8.1147E-05	1.3625E-04
13032	61)	-3.4164E-04	4.5207E-03	-5.6270E-03	-5.5000E-04	6.0243E-05	2.0076E-05
44	67)	-1.0132E-03	-3.1719E-03	-5.9923E-03	3.7515E-04	-1.0437E-05	-4.3268E-05
16020	73)	-1.3770E-03	-5.0990E-03	6.7729E-04	-2.4946E-04	7.7392E-05	3.1760E-05
13008	79)	6.1029E-05	4.5270E-03	5.0700E-03	-5.4832E-04	6.5113E-05	2.0123E-05
32	85)	-1.1254E-03	-5.9309E-03	9.7128E-03	-2.3011E-06	-3.9625E-05	4.8066E-07
23	91)	6.7038E-04	-4.7581E-03	5.9394E-03	2.2761E-04	-1.1270E-04	2.1283E-05
24	97)	-8.4681E-04	-7.6162E-03	5.7734E-03	-1.6647E-04	-7.6902E-05	-1.2994E-05
16030	103)	6.1106E-04	-6.1879E-03	-5.8134E-05	2.3490E-04	-1.0931E-04	2.4546E-05
12	109)	3.3850E-04	-8.0386E-03	-6.6956E-03	-2.1903E-04	-5.7104E-05	-1.1436E-05
1	115)	1.5724E-03	-5.9704E-03	-1.3810E-02	1.6501E-04	-5.4207E-05	8.2962E-06
13051	121)	-3.3405E-04	5.0845E-03	-7.3690E-03	-5.4516E-04	6.1982E-05	1.9942E-05
13049	127)	-1.3906E-04	4.9653E-03	-1.6864E-03	-5.4437E-04	6.2657E-05	1.9992E-05
13000	133)	5.4525E-05	5.0835E-03	3.2412E-03	-5.4453E-04	6.3332E-05	1.9652E-05
13011	139)	7.2035E-05	3.6630E-03	7.6632E-03	-5.5466E-04	6.4463E-05	2.2019E-05
13050	145)	-1.4135E-04	3.7938E-03	1.8629E-03	-5.5585E-04	6.3103E-05	2.1822E-05
13039	151)	-3.5485E-04	3.6602E-03	-3.1930E-03	-5.5728E-04	6.1743E-05	2.2043E-05
13061	157)	-1.4795E-03	-6.3344E-03	-3.5662E-03	-5.6112E-04	6.2388E-05	2.2148E-05
1200	163)	1.2841E-03	-6.0394E-03	-1.3881E-02	-1.6746E-04	-4.3835E-05	-4.2630E-05
15010	169)	-1.1569E-04	-6.1440E-03	-7.3353E-03	-3.2511E-04	1.1102E-04	-4.1255E-05
15050	175)	-1.9967E-03	-6.2560E-03	6.5205E-03	-3.9321E-04	1.4193E-04	-4.7979E-05
1226	181)	-4.3457E-03	-9.4844E-03	1.6207E-02	-3.9338E-04	1.4203E-04	-4.7996E-05

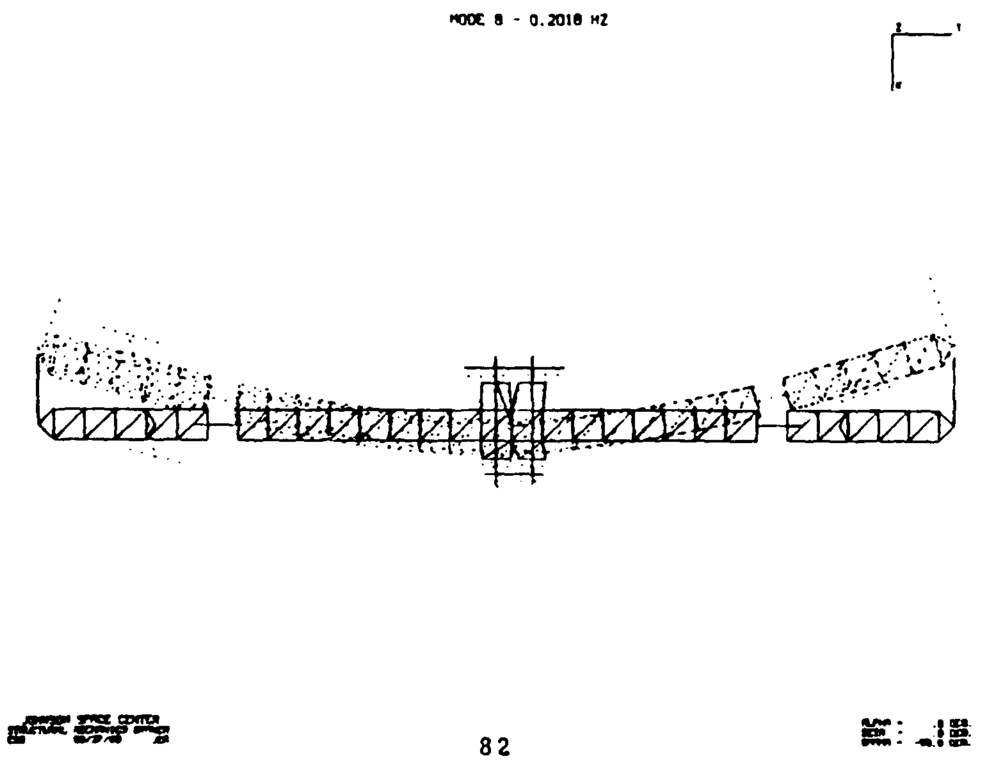
APPENDIX B

Structural Flexible Modes

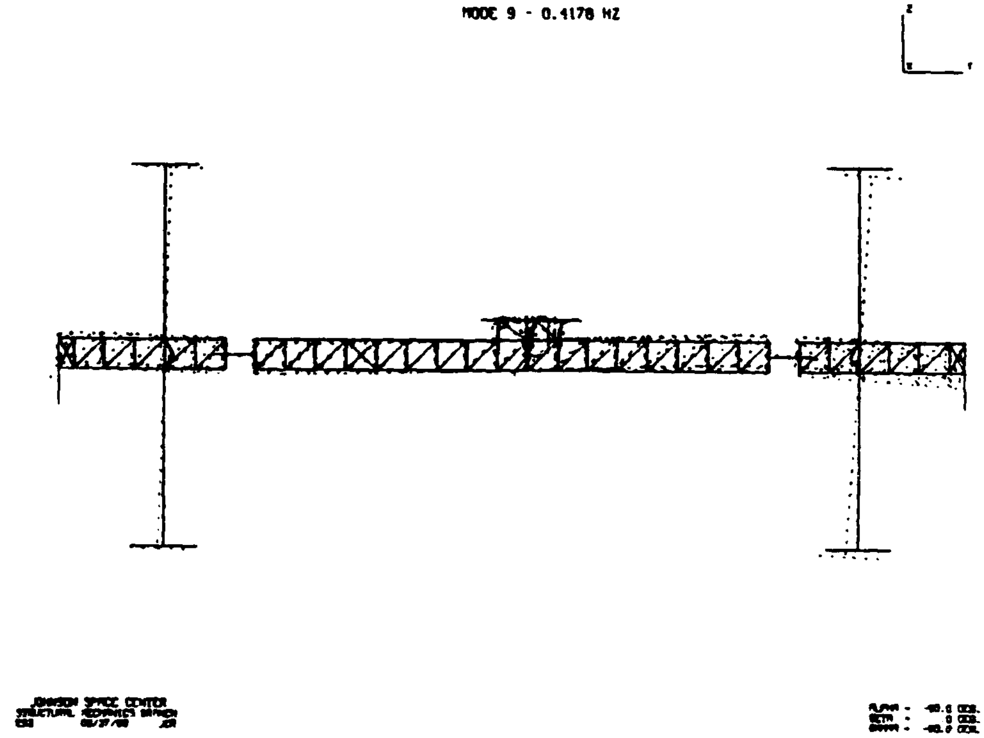

MODE 7 - 0.1953 HZ
JOHNSON SPACE CENTER
STRUCTURAL MECHANICS BRANCH


MODE 7 - 0.1953 HZ
JOHNSON SPACE CENTER
STRUCTURAL MECHANICS BRANCH

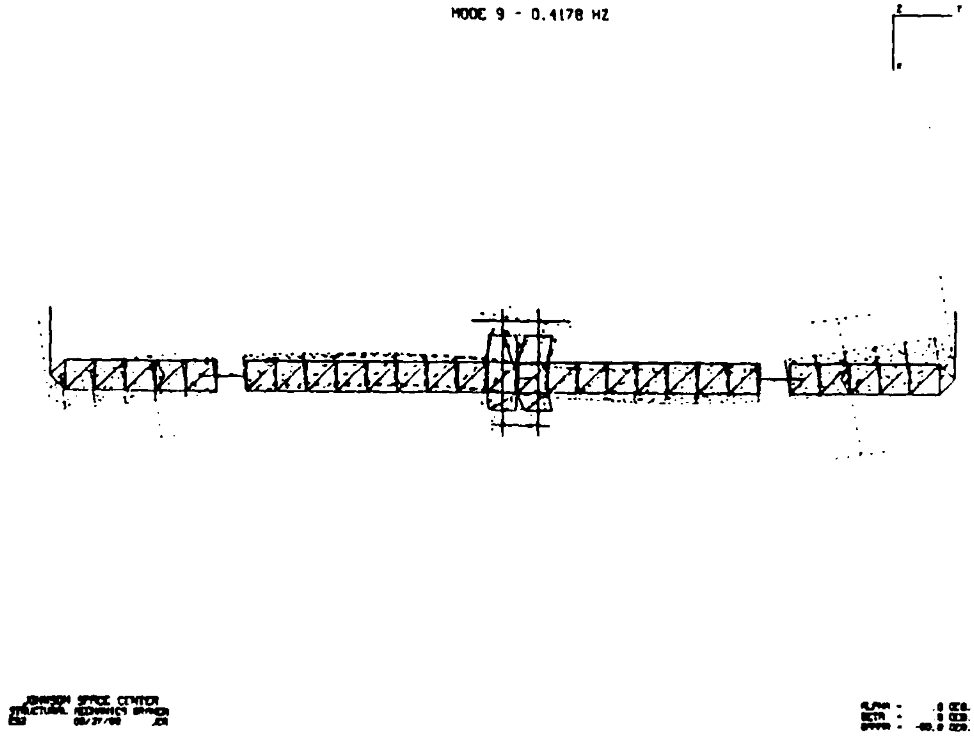

MODE 8 - 0.2018 HZ
JOHNSON SPACE CENTER


MODE 8 - 0.2018 HZ
JOHNSON SPACE CENTER

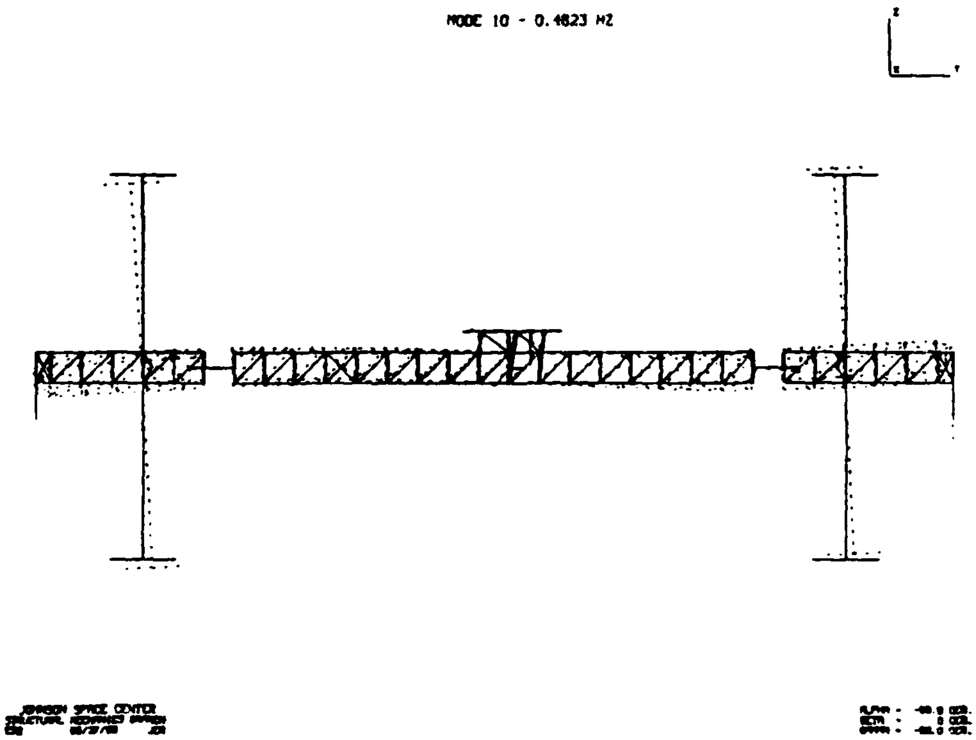
MODE 9 - 0.4178 HZ



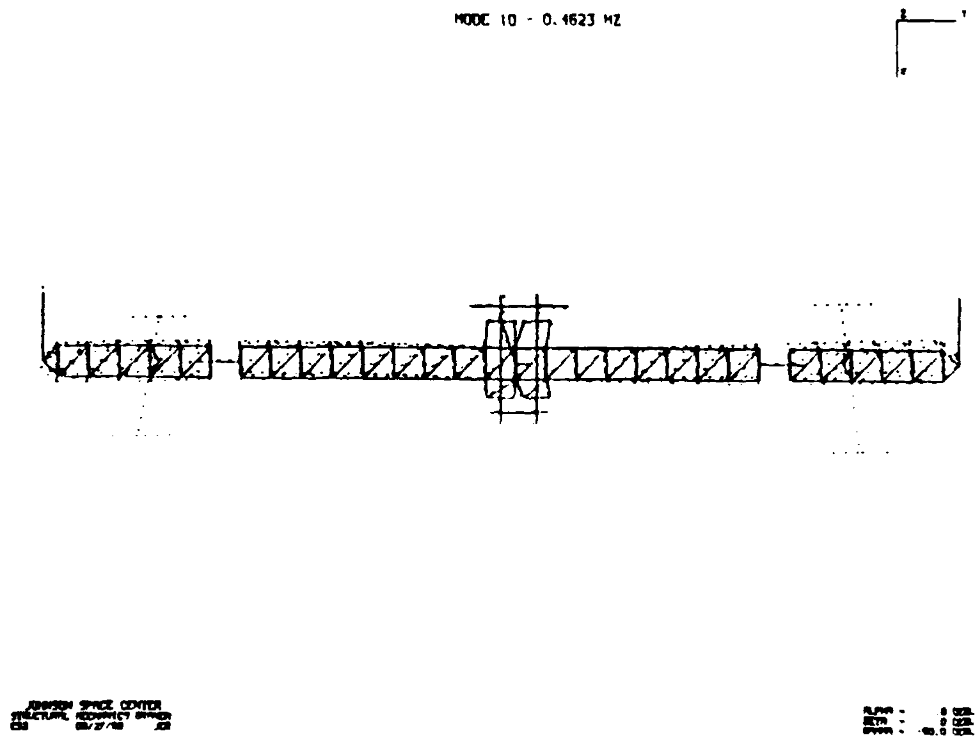
MODE 9 - 0.4178 HZ



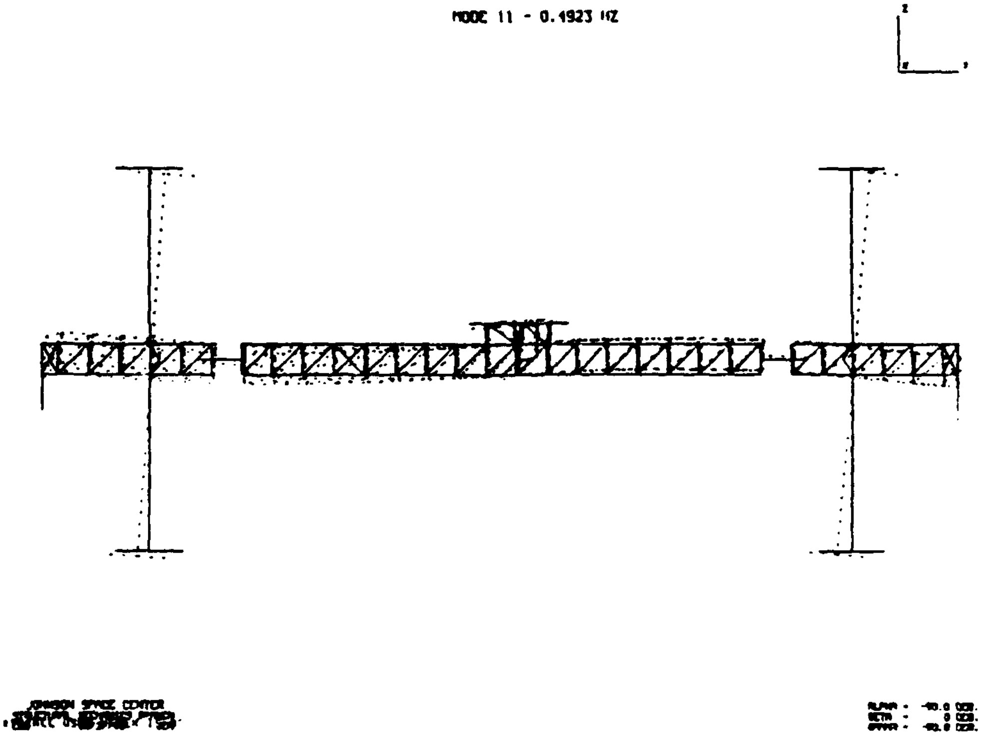
MODE 10 - 0.4823 HZ



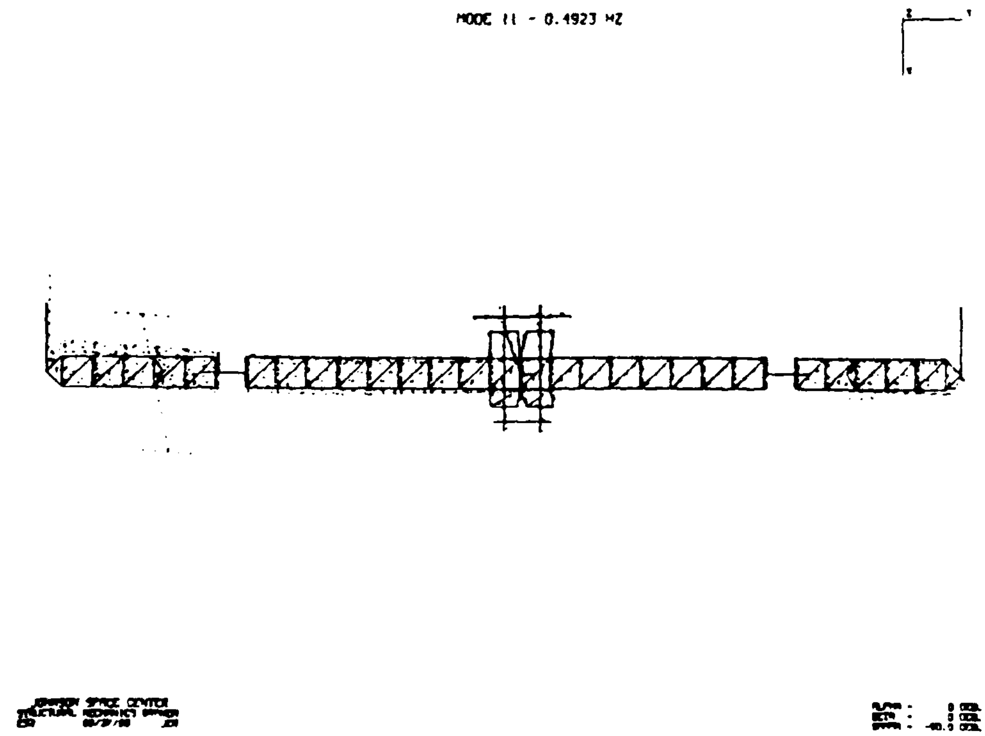
MODE 10 - 0.4823 HZ



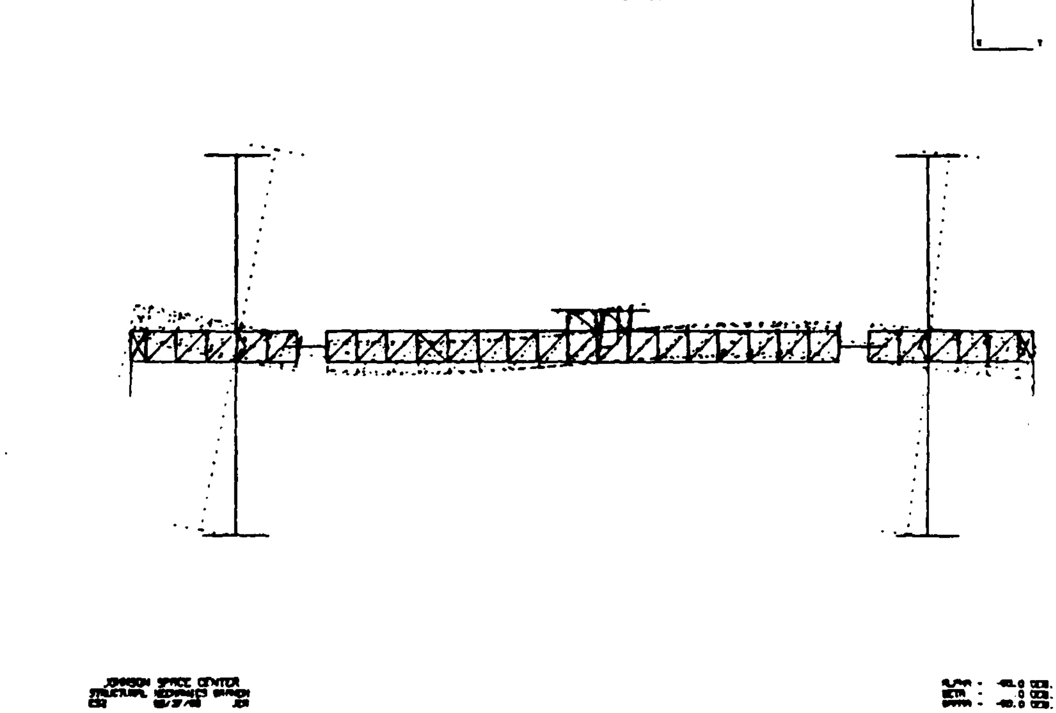
MODE 11 - 0.4923 HZ



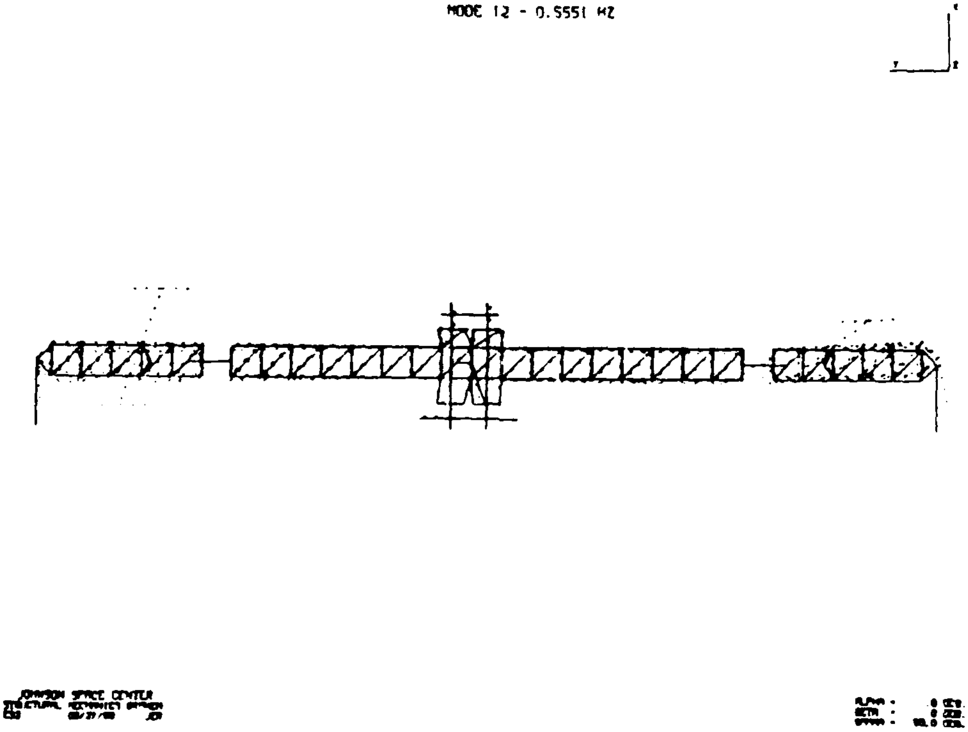
MODE 11 - 0.4923 HZ



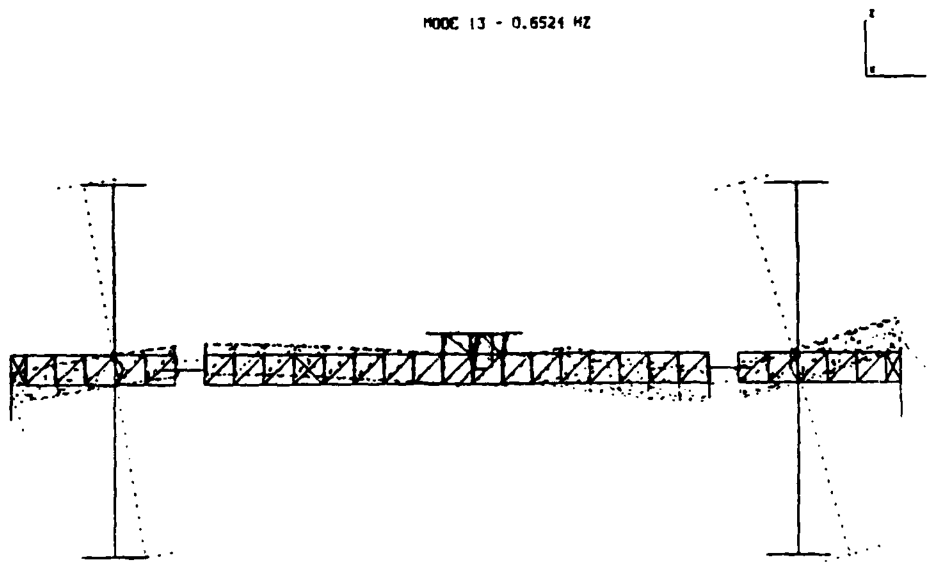
MODE 12 - 0.5551 HZ



MODE 12 - 0.5551 HZ



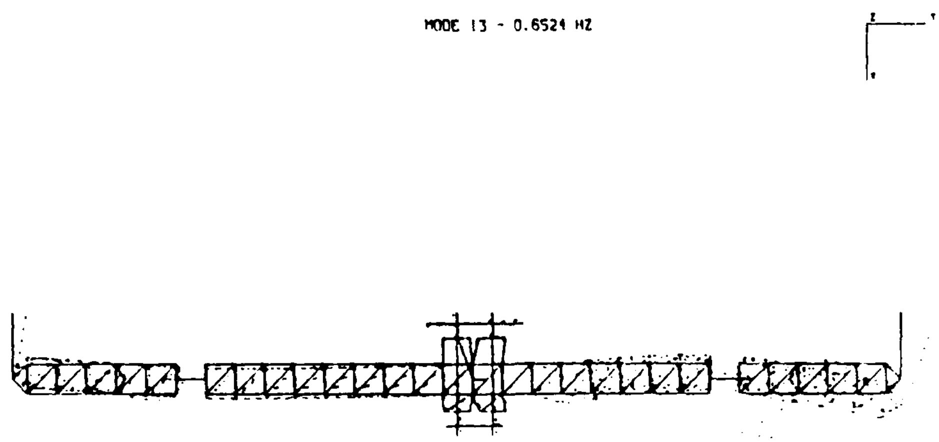
MODE 13 - 0.6524 HZ



JOHNSON SPACE CENTER
STRUCTURAL MECHANICS BRANCH

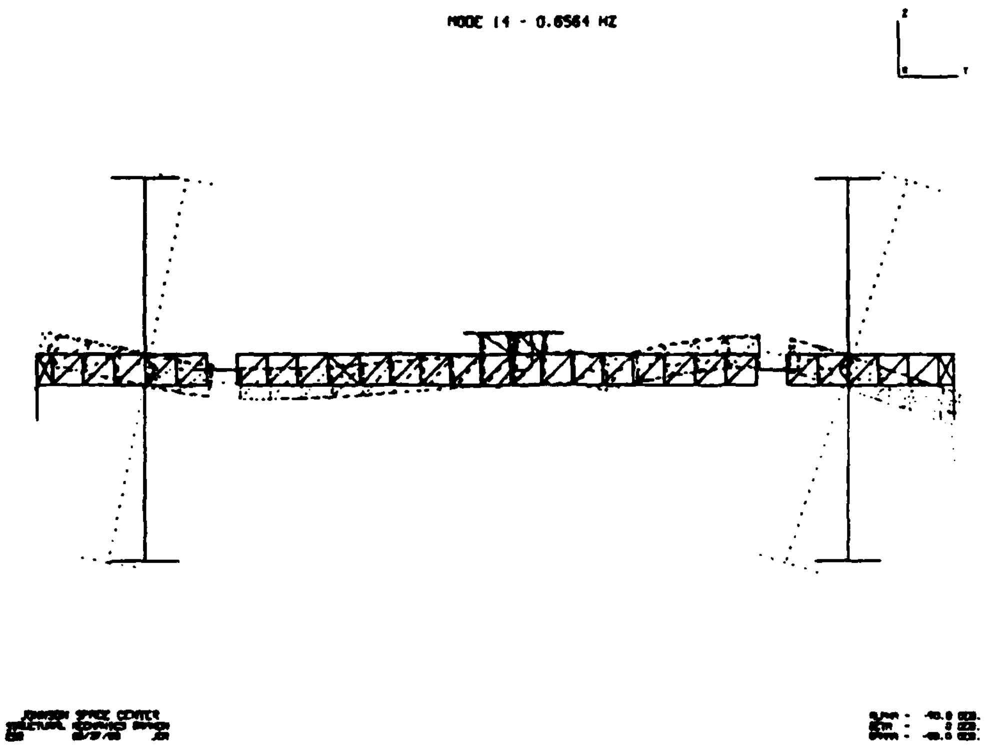
ALPHA : -90.0 DEG.
BETA : .3 DEG.
GAMMA : -90.0 DEG.

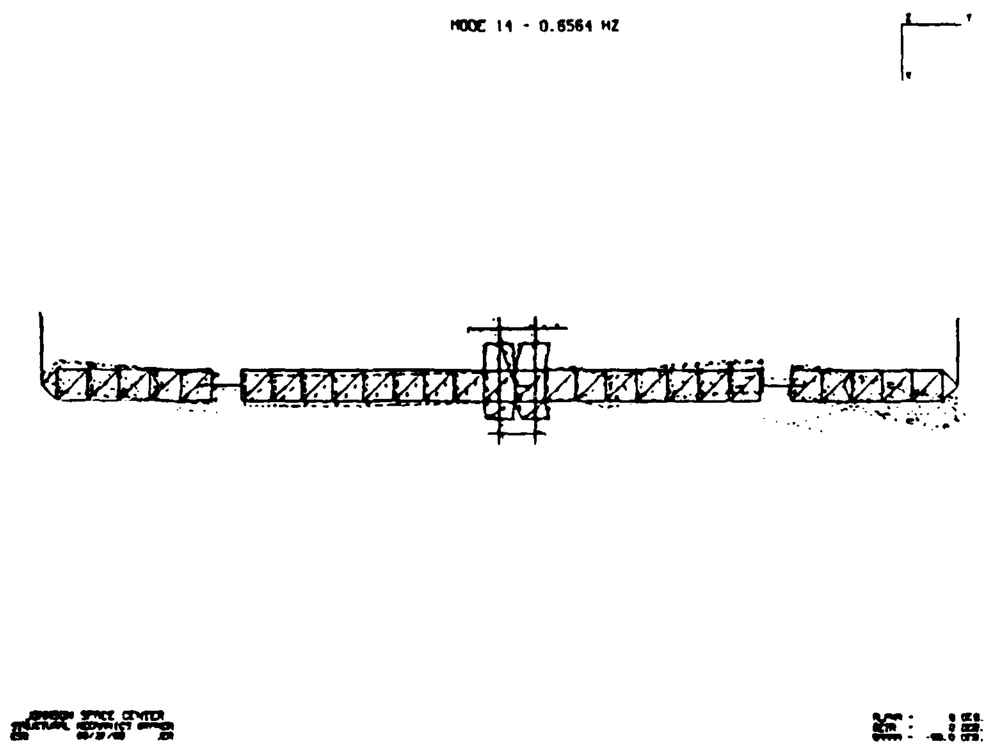
MODE 13 - 0.6524 HZ

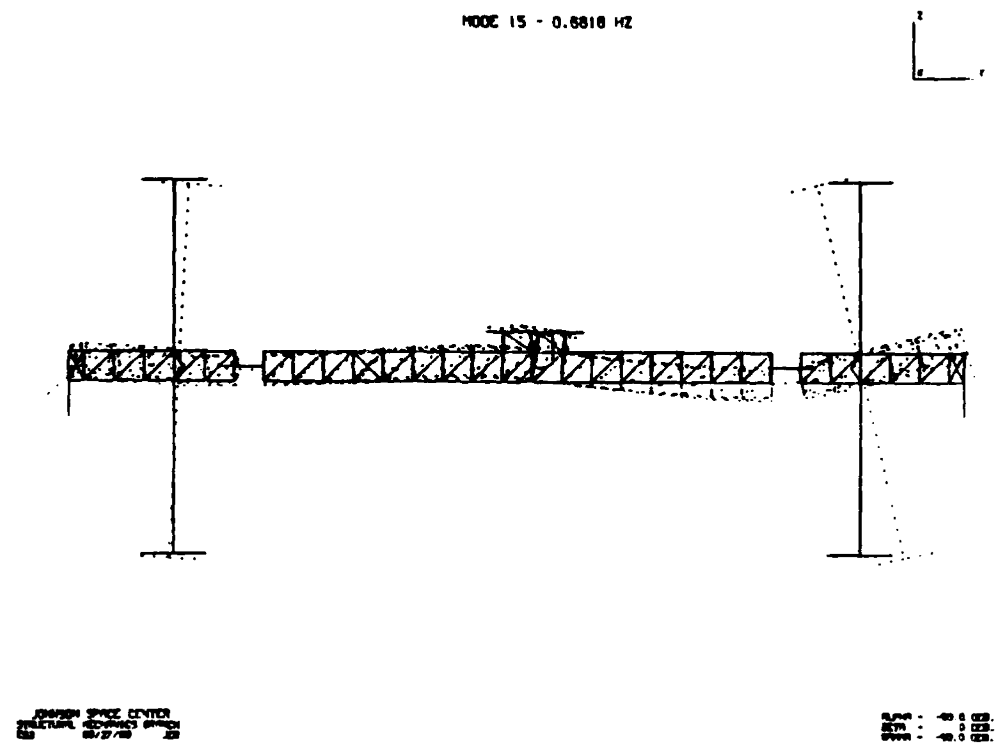


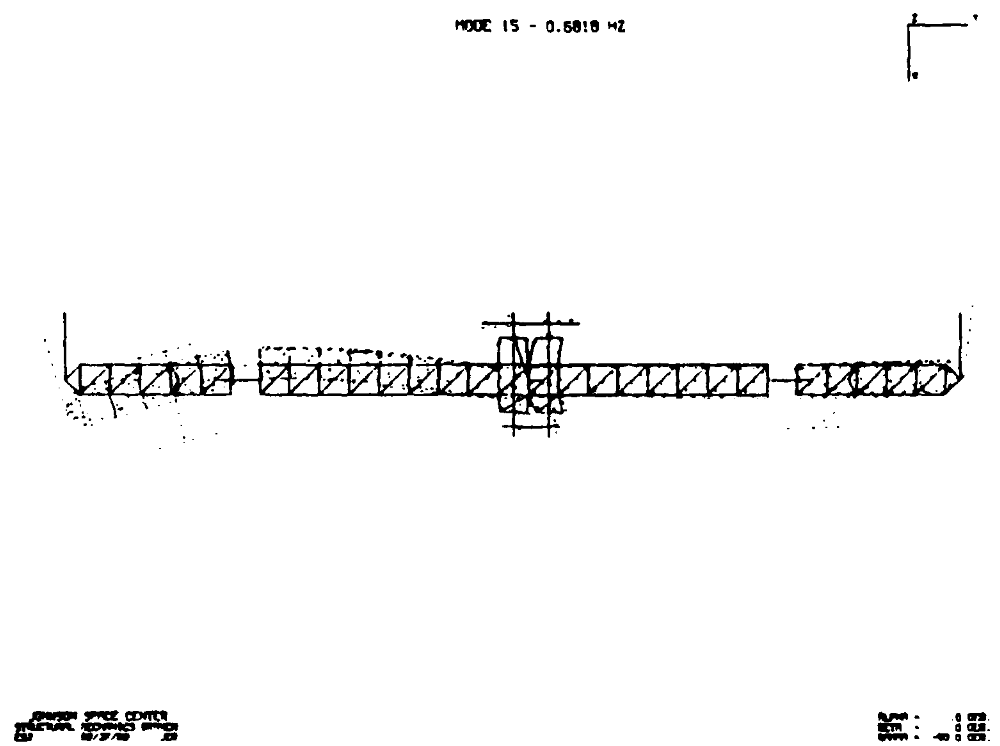
JOHNSON SPACE CENTER
STRUCTURAL MECHANICS BRANCH

ALPHA : 0 DEG.
BETA : 0 DEG.
GAMMA : -90.0 DEG.

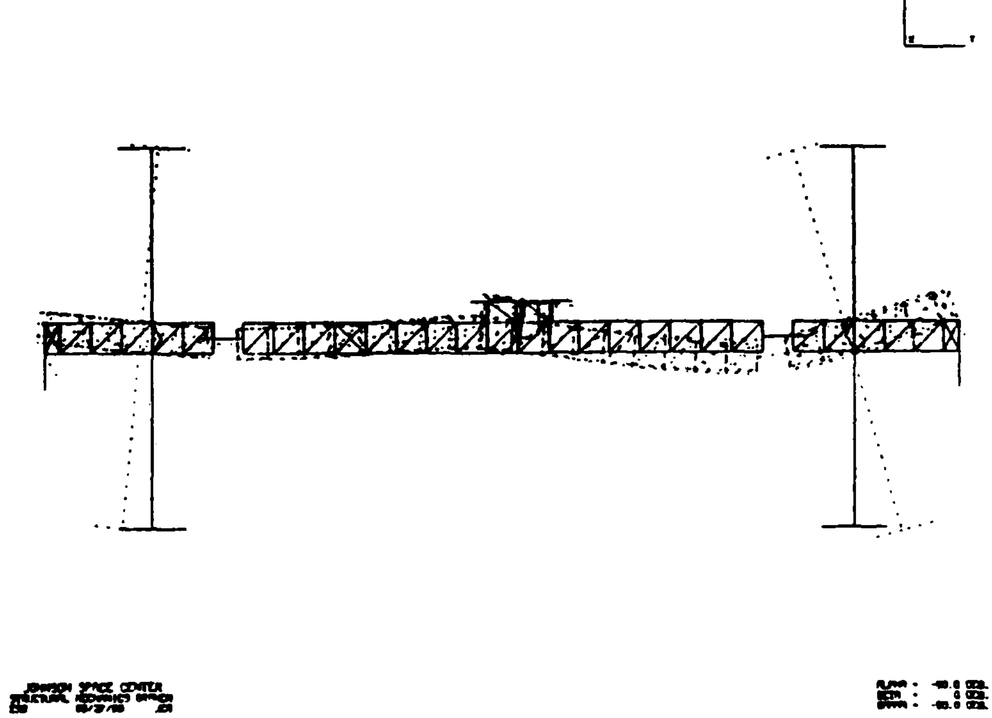

MODE 14 - 0.6564 HZ


MODE 14 - 0.6564 HZ

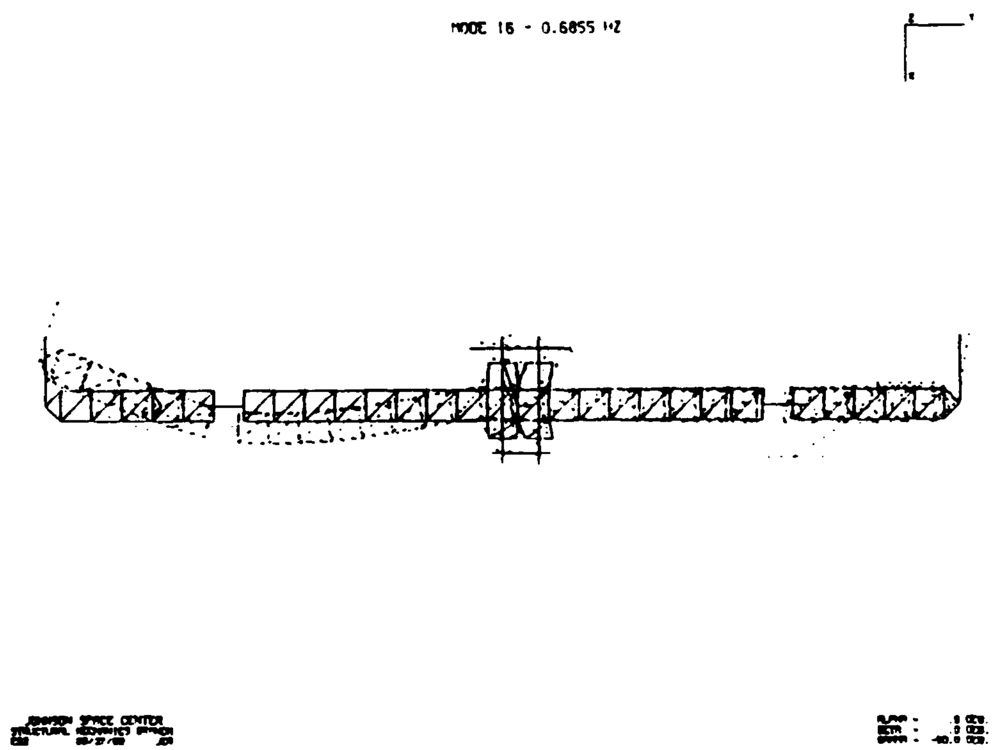

MODE 15 - 0.6818 HZ
JOHNSON SPACE CENTER
STRUCTURAL MECHANICS BRANCH
ALPHA : -90.0 DEG.
BETA : 0 DEG.
GAMMA : -90.0 DEG.


MODE 15 - 0.6818 HZ
JOHNSON SPACE CENTER
STRUCTURAL MECHANICS BRANCH
ALPHA : 0 DEG.
BETA : 0 DEG.
GAMMA : -90 0 DEG.

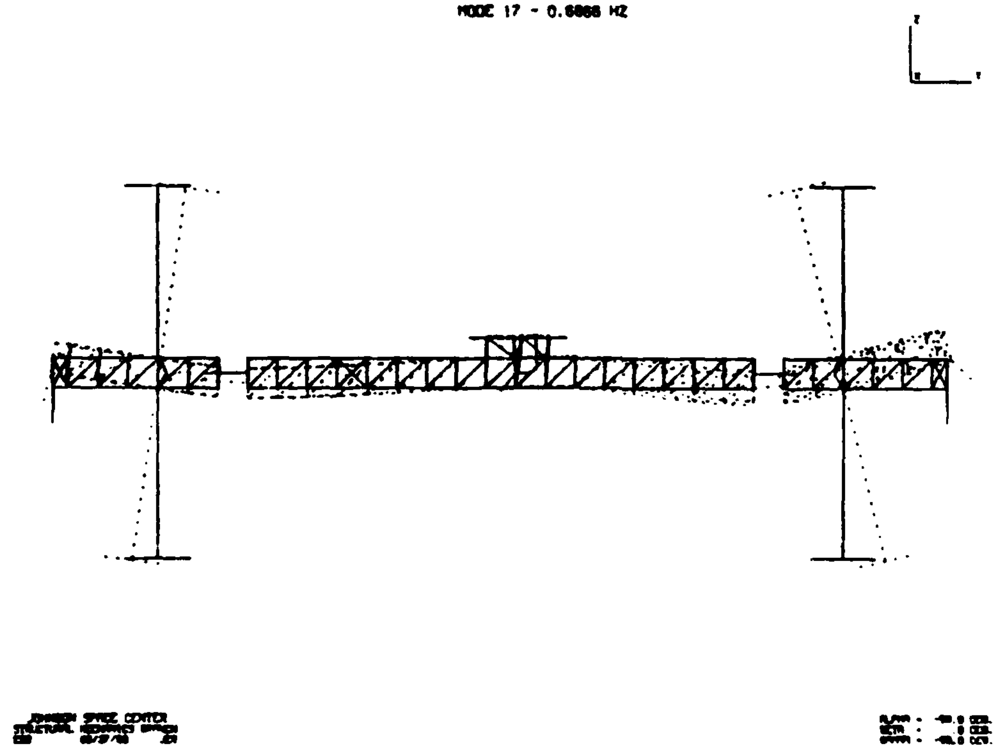
MODE 16 - 0.6855 HZ



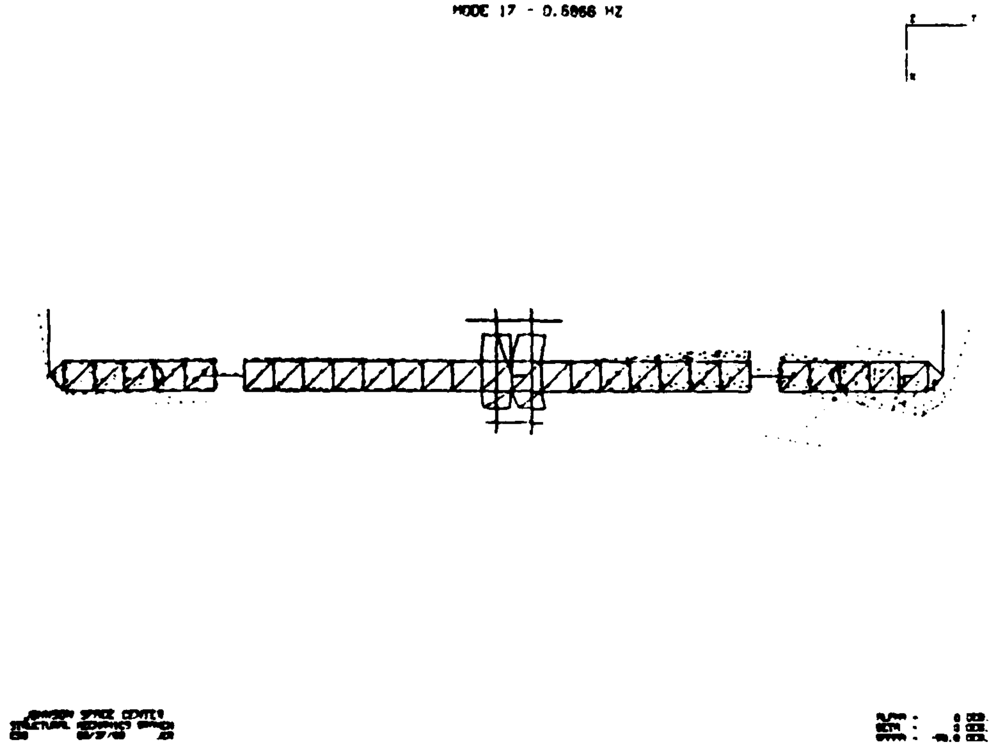
MODE 16 - 0.6855 HZ

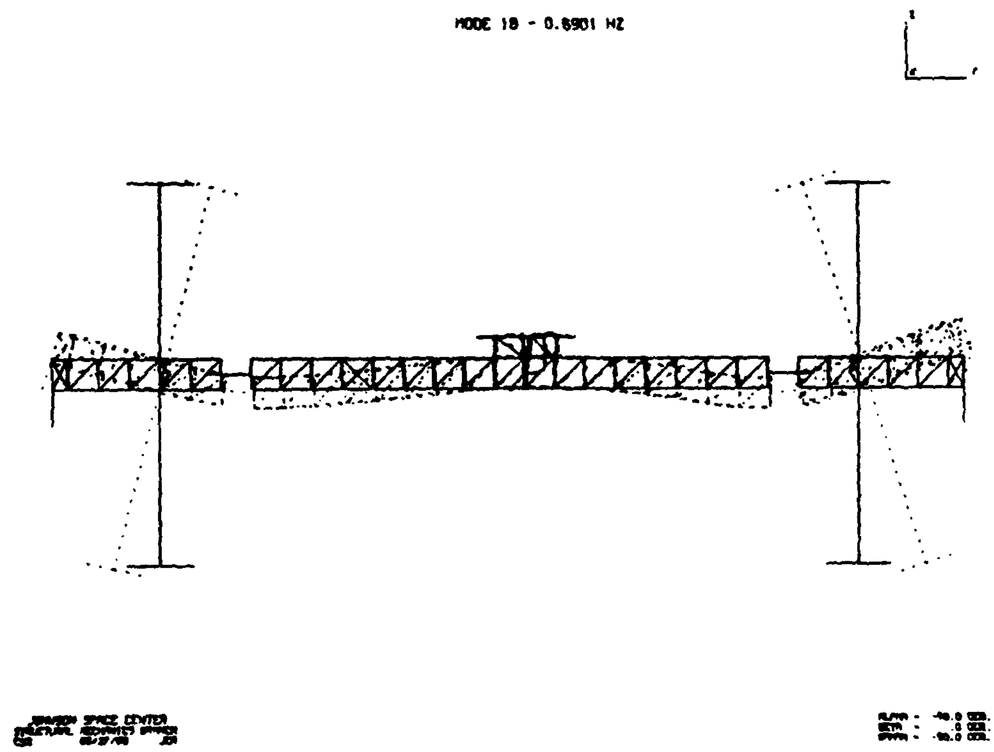


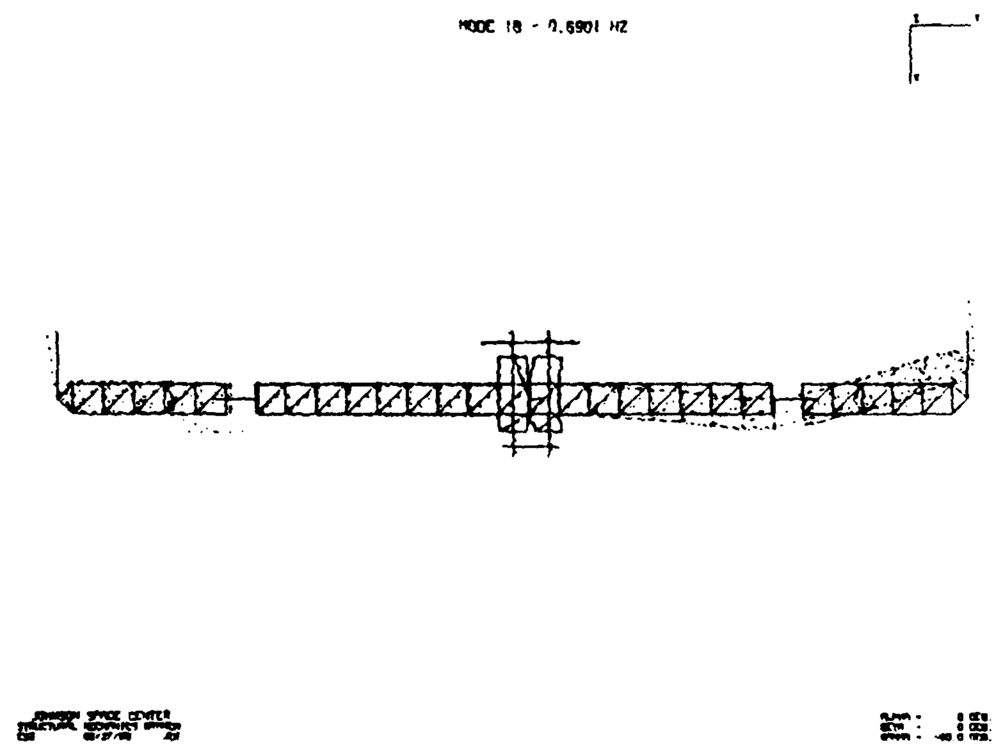
MODE 17 - 0.6868 HZ

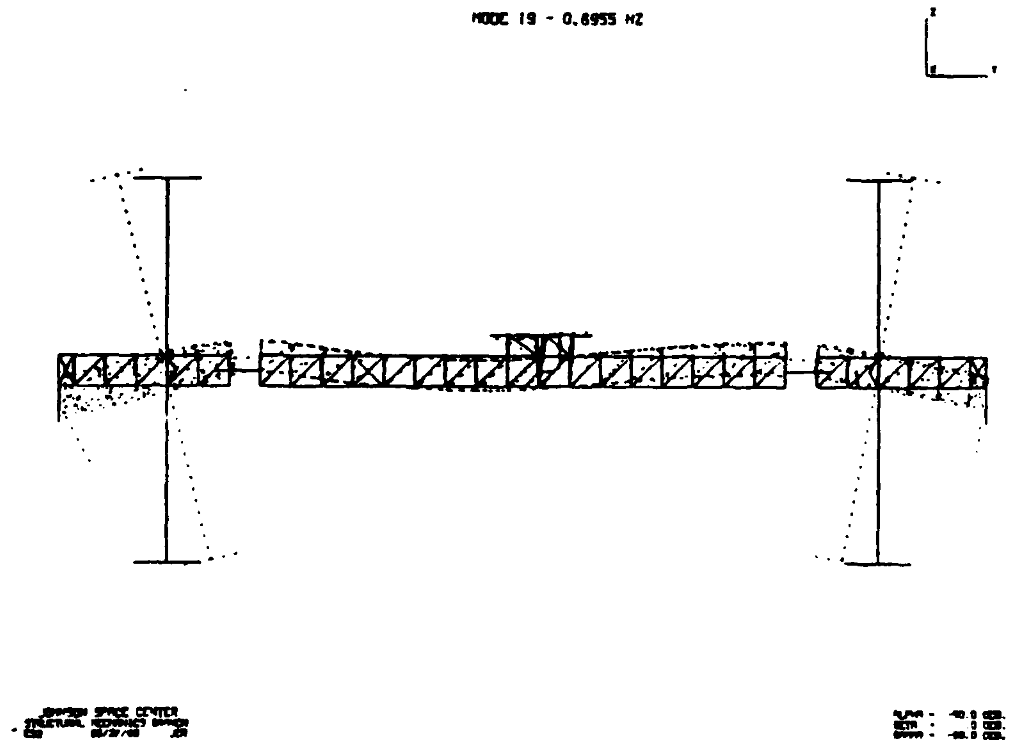


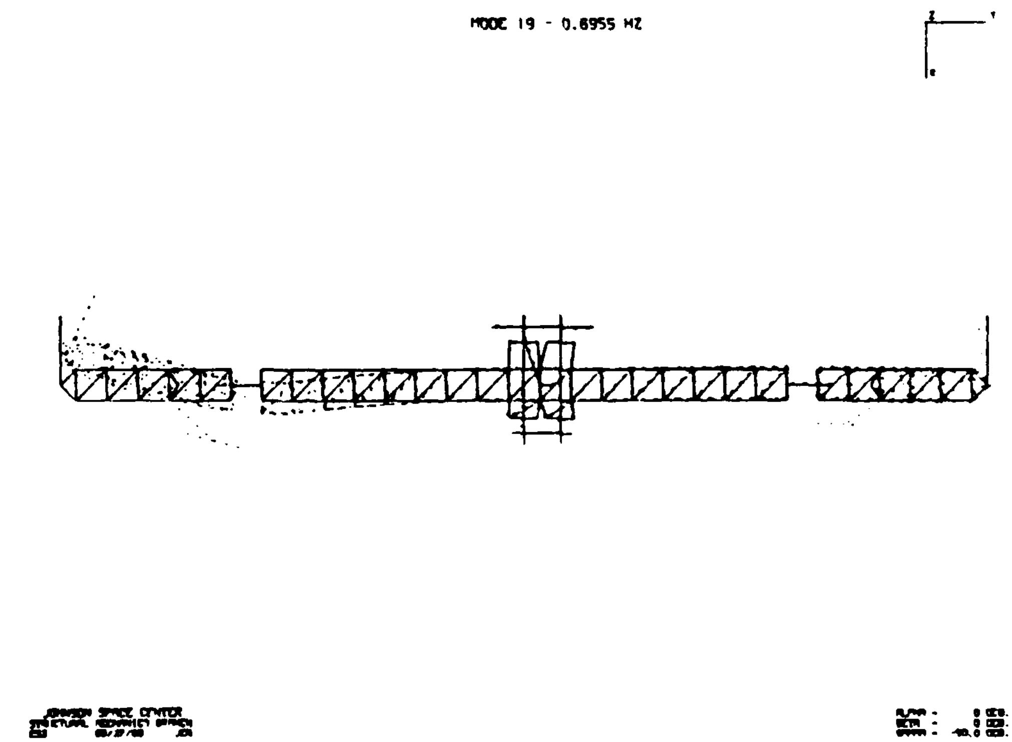
MODE 17 - 0.6868 HZ

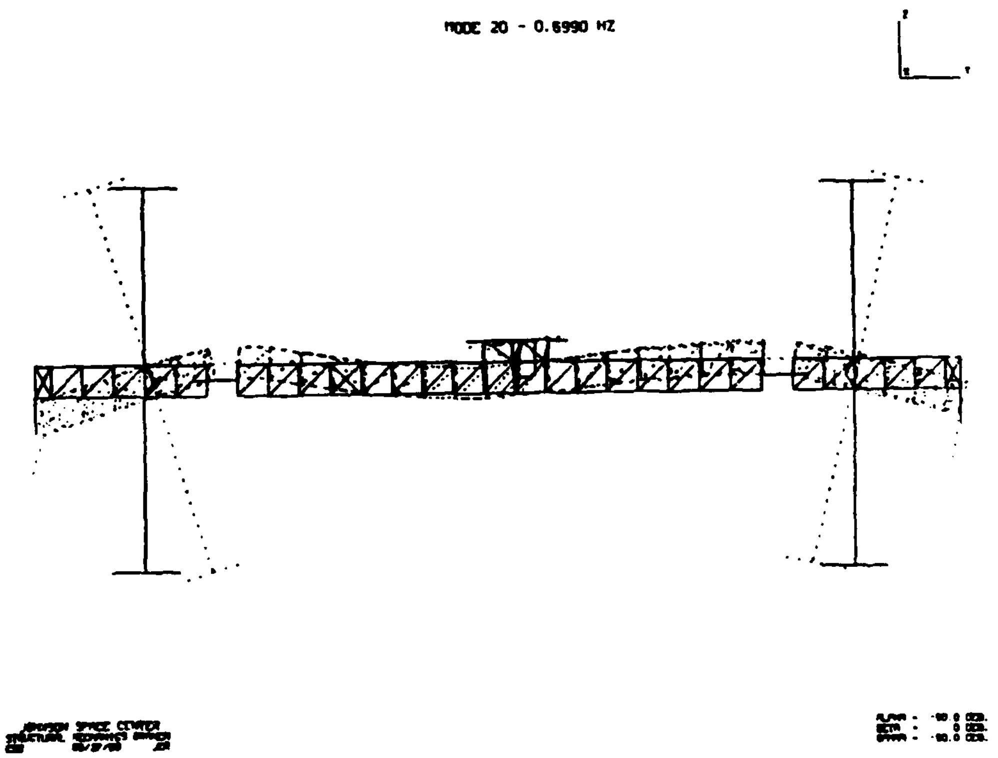


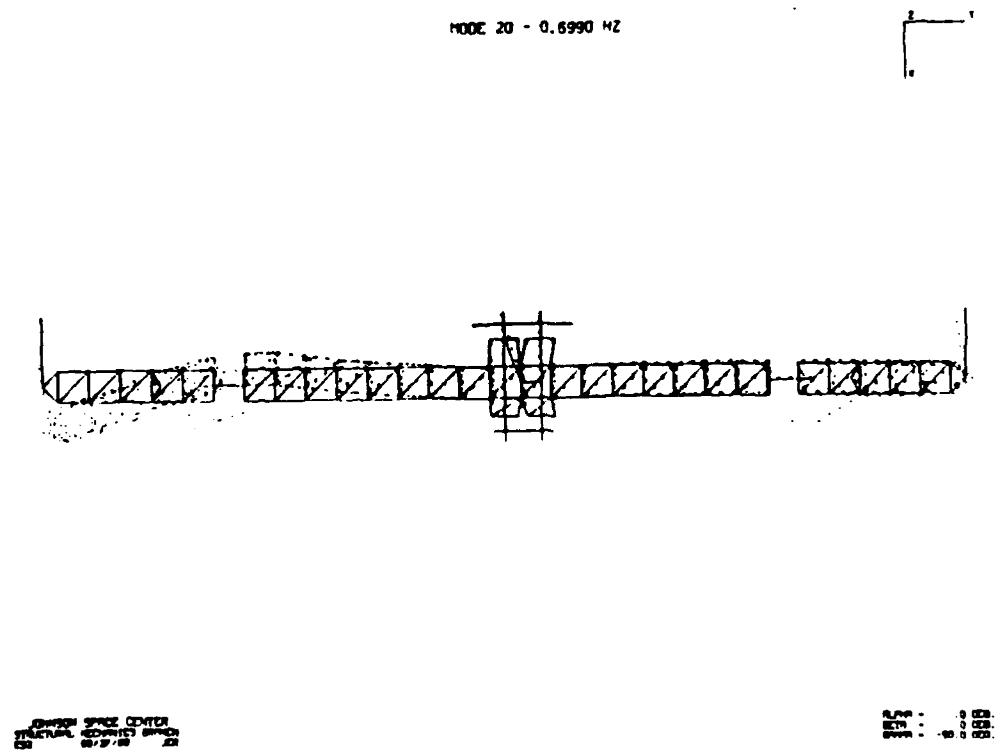

MODE 18 - 0.6901 HZ

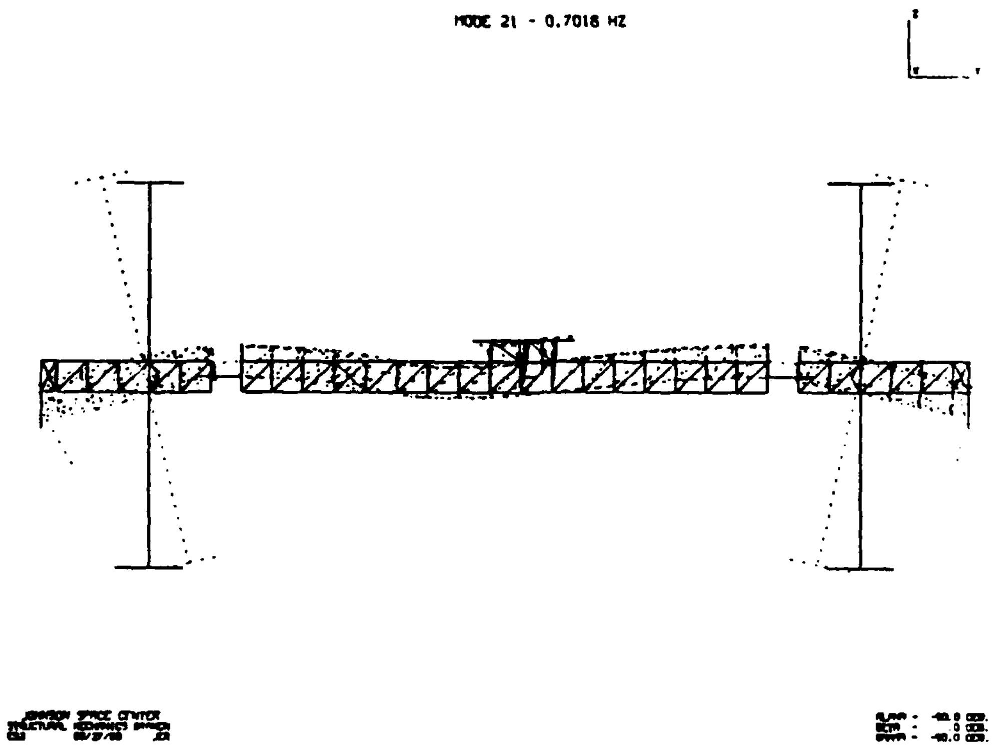

MODE 18 - 0.6901 HZ

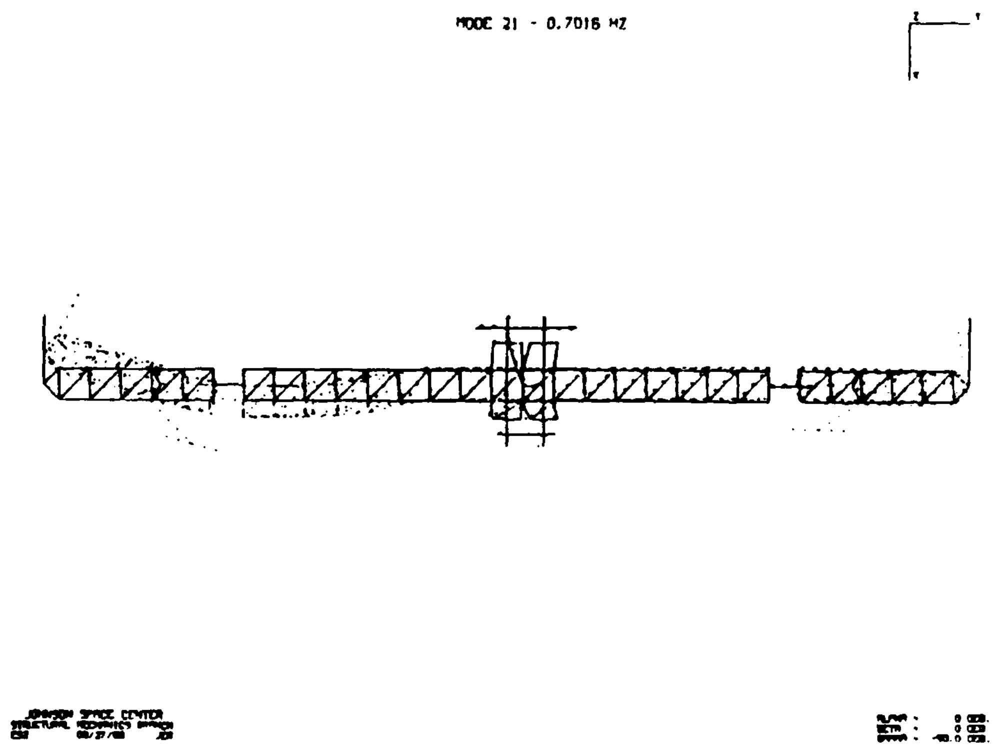

MODE 19 - 0.6955 HZ
JOHNSON SPACE CENTER
STRUCTURAL MECHANICS BRANCH

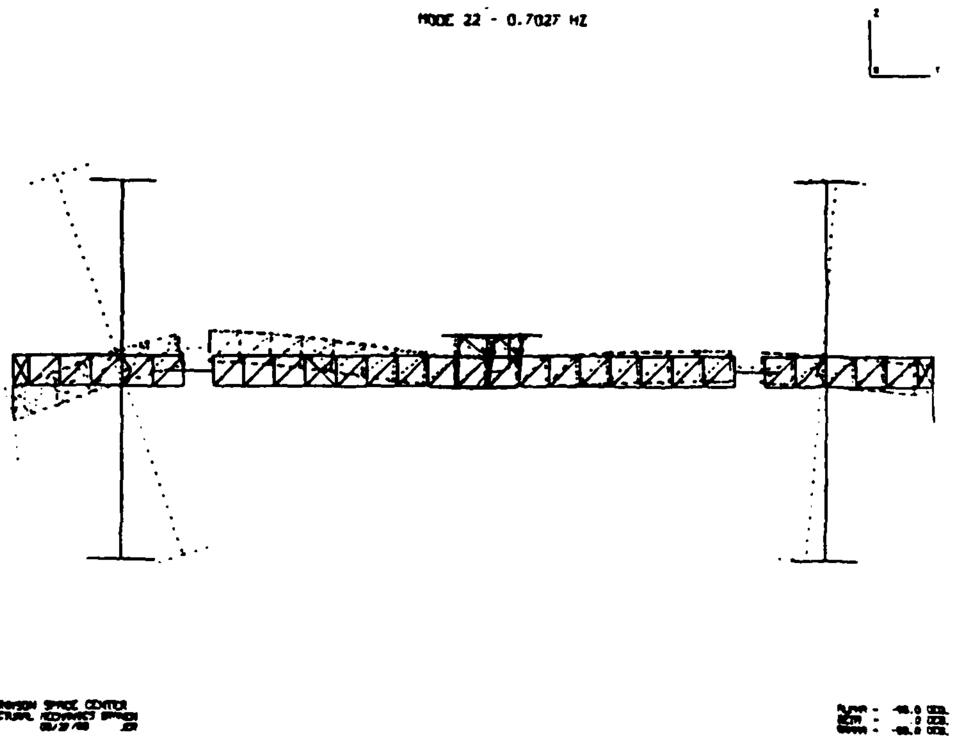

MODE 19 - 0.6955 HZ
JOHNSON SPACE CENTER
STRUCTURAL MECHANICS BRANCH


MODE 20 - 0.6990 HZ


MODE 20 - 0.6990 HZ


MODE 21 - 0.7016 HZ


MODE 21 - 0.7016 HZ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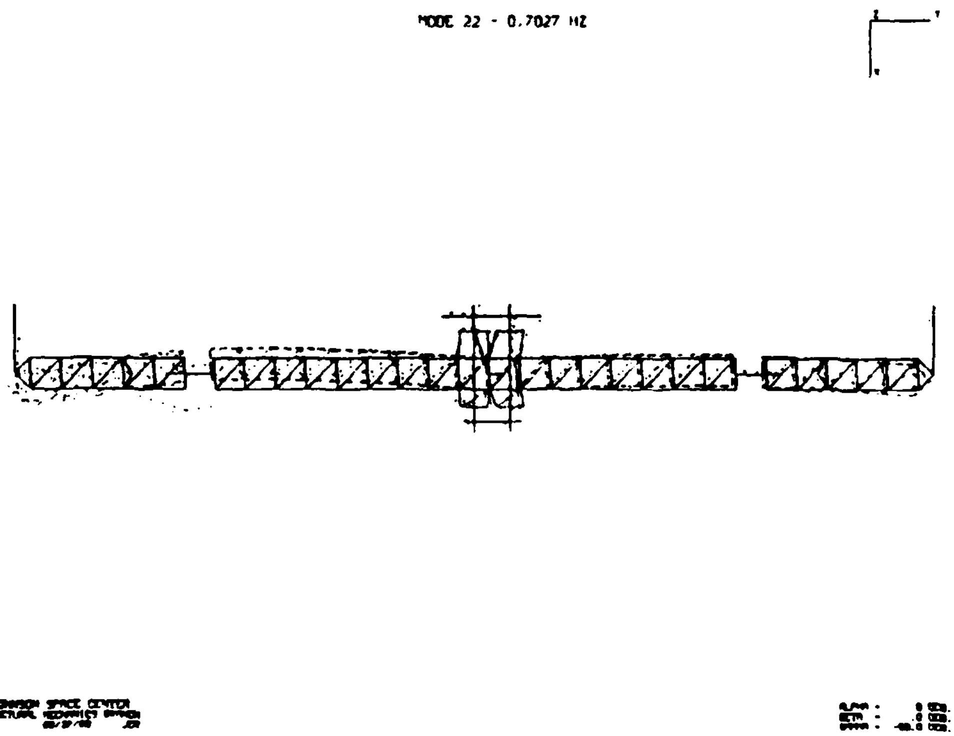
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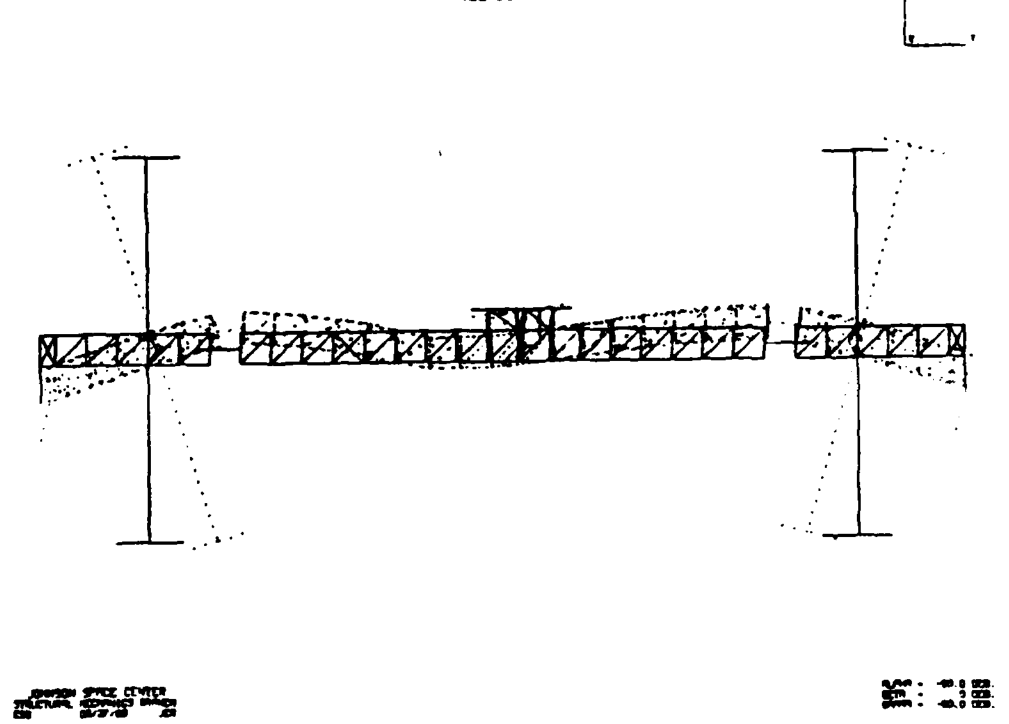

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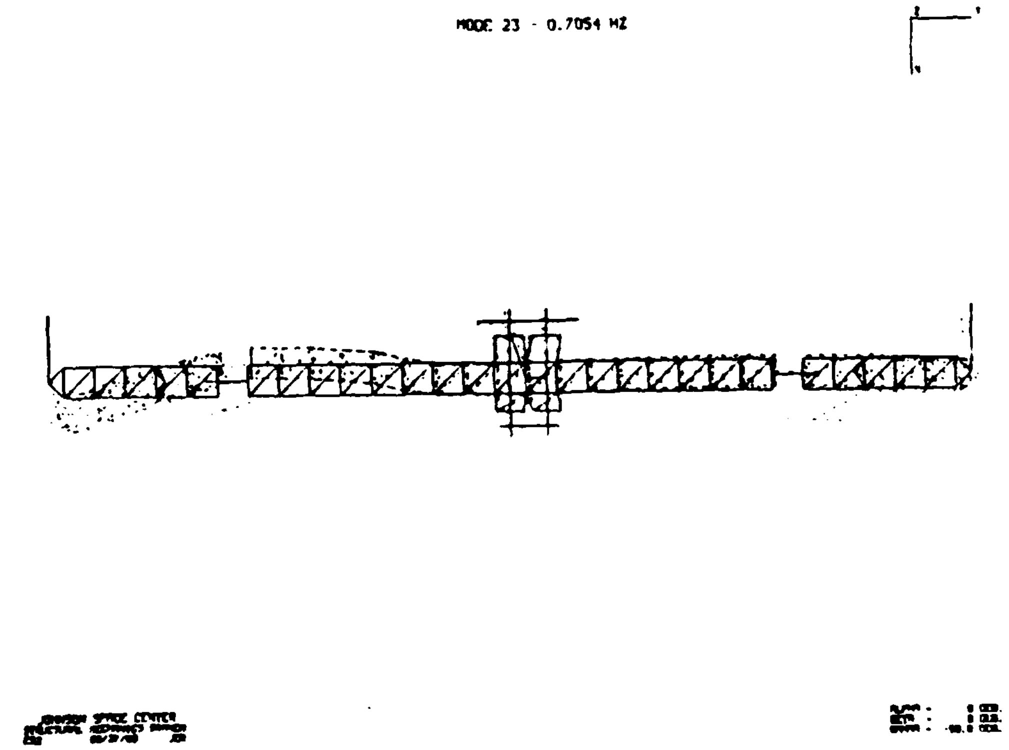

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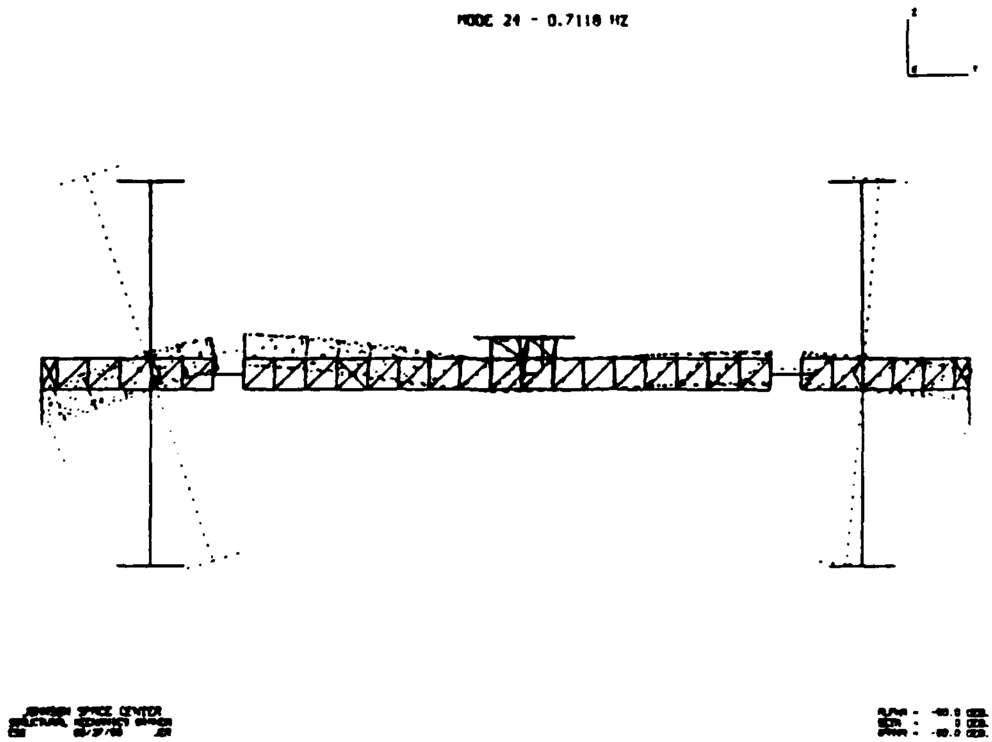

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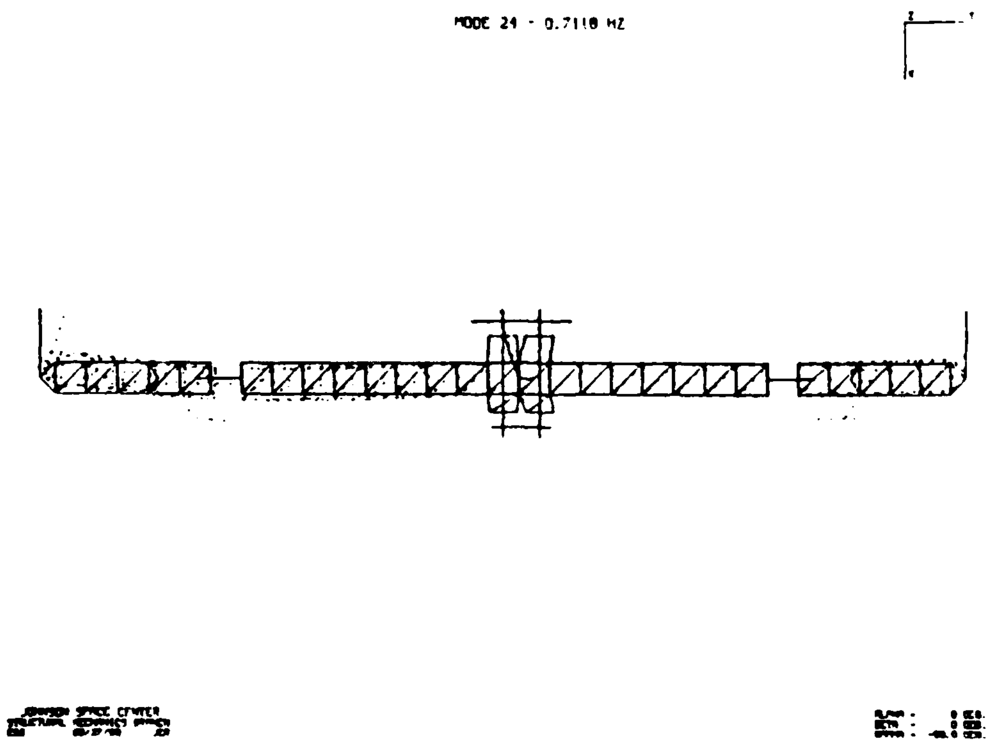

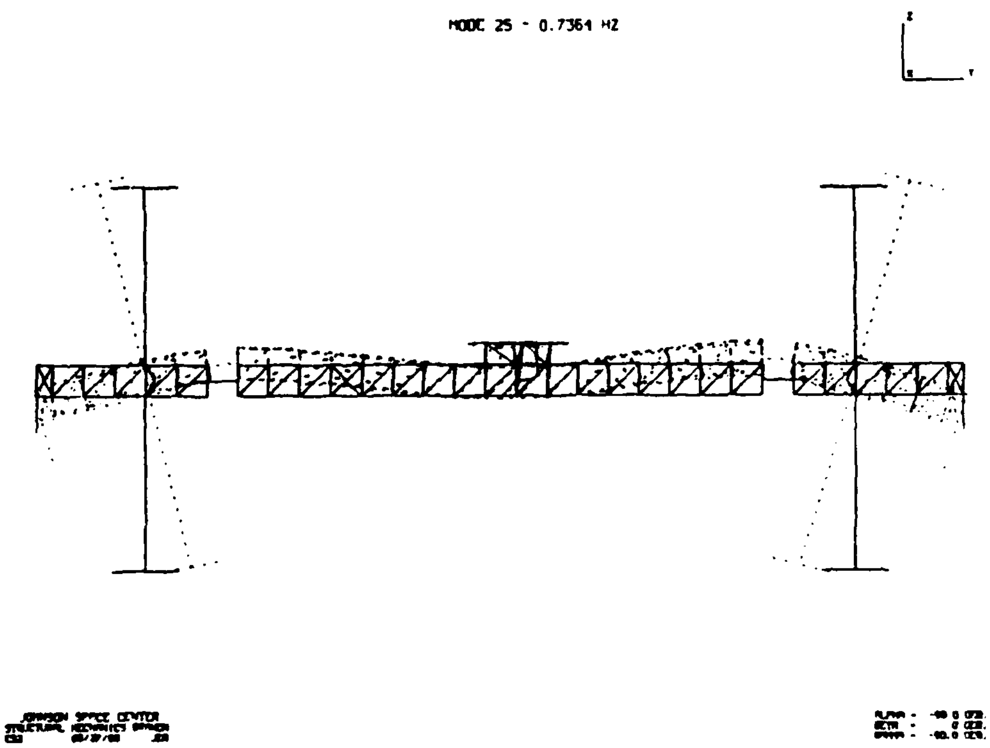
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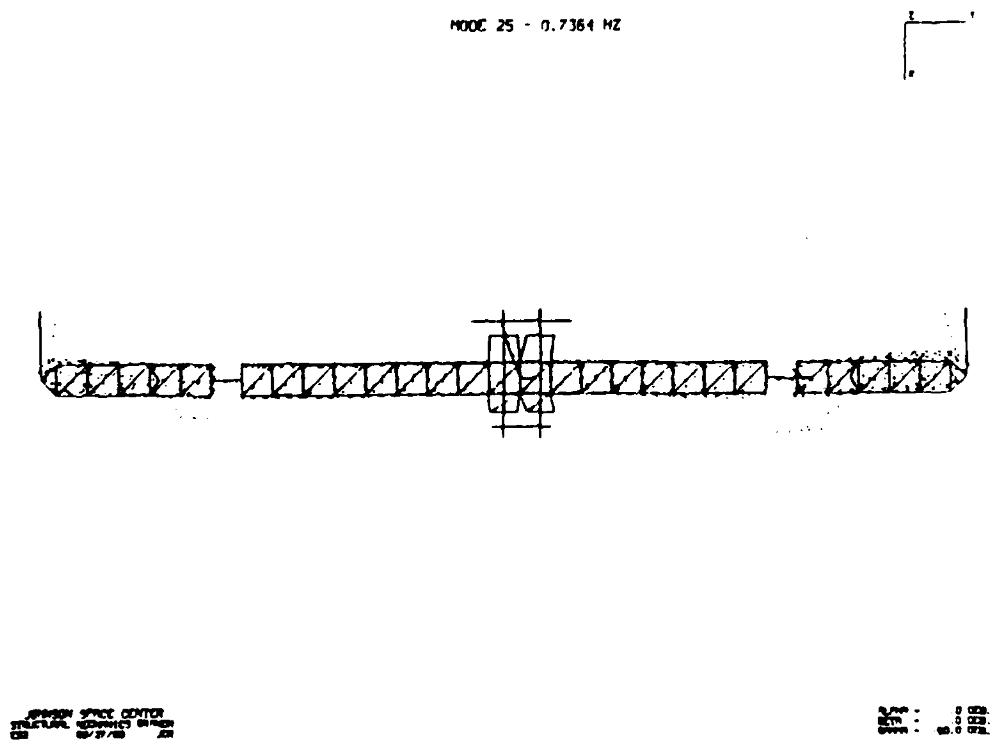
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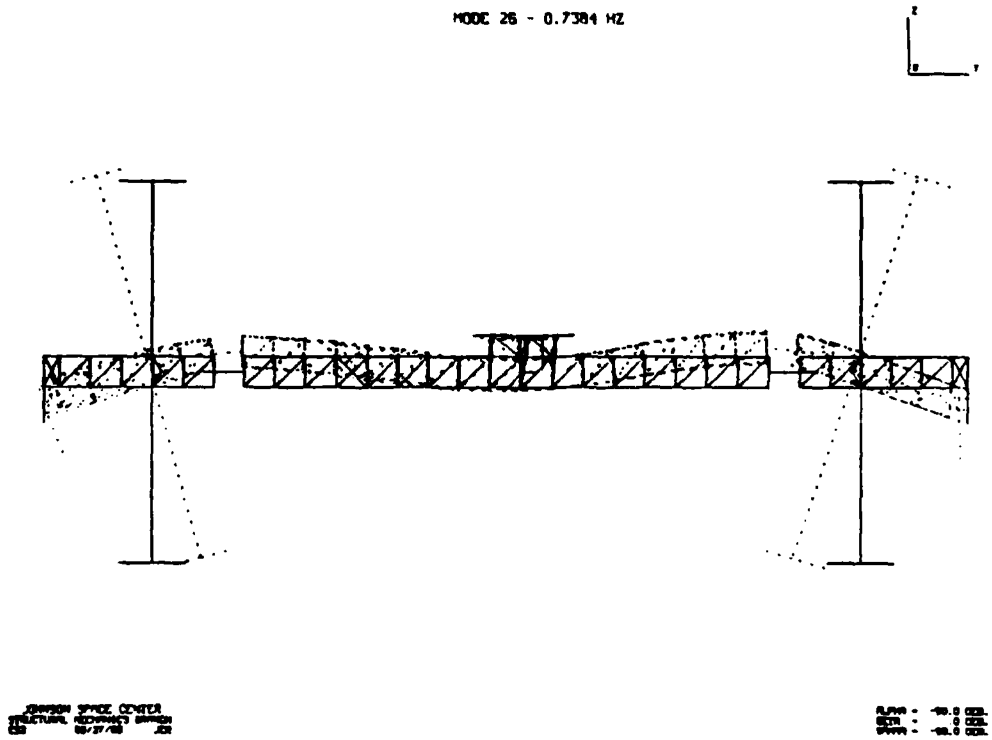
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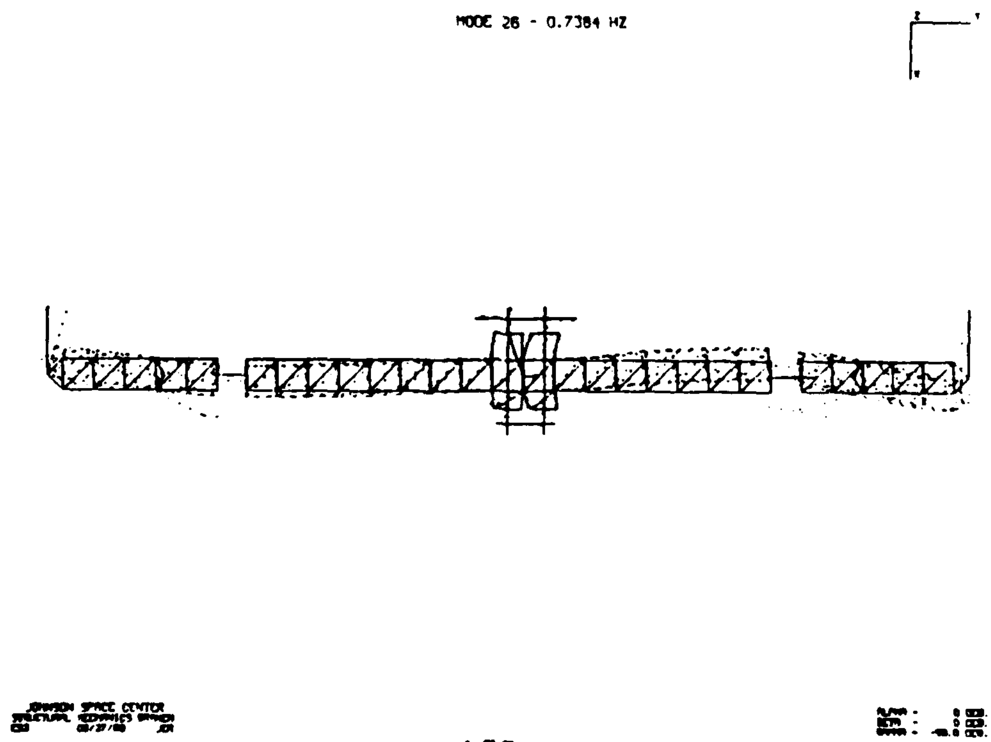
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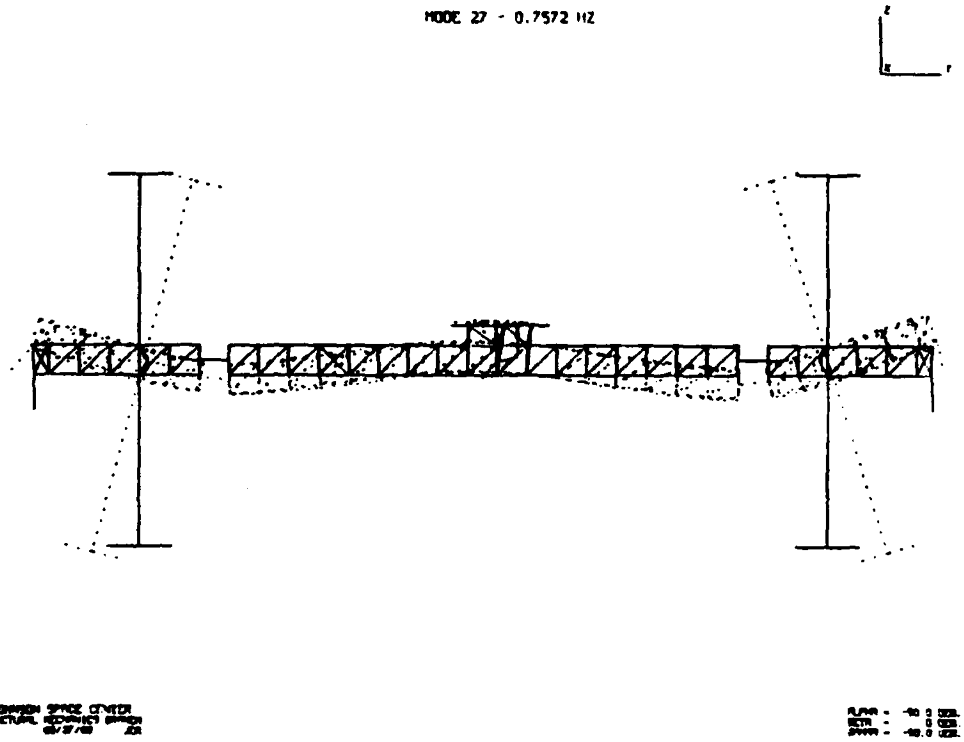

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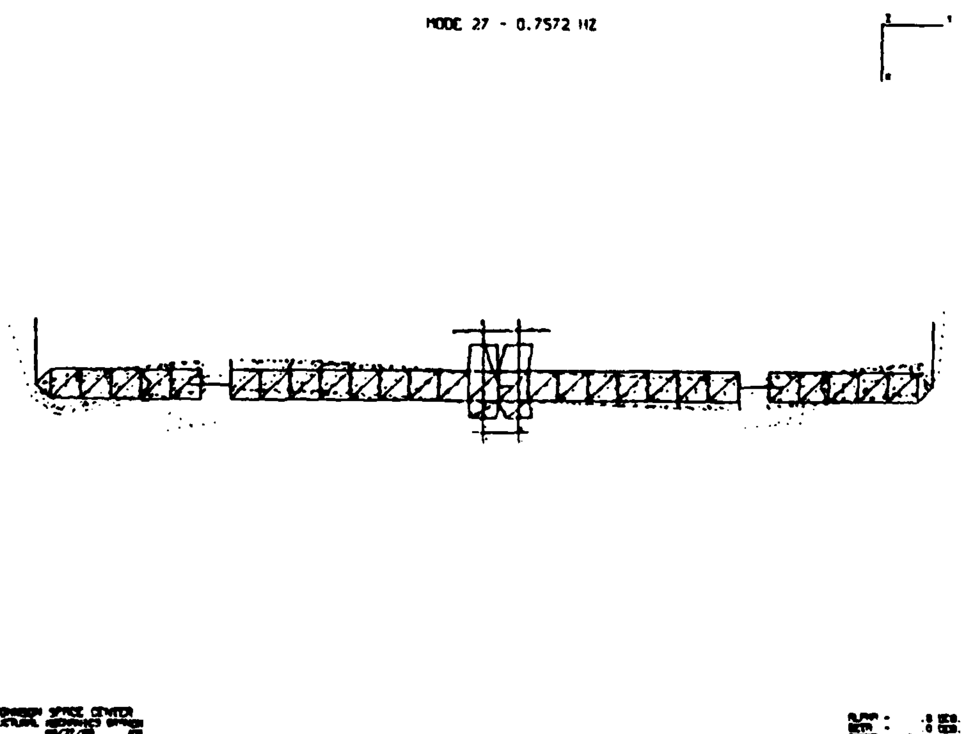

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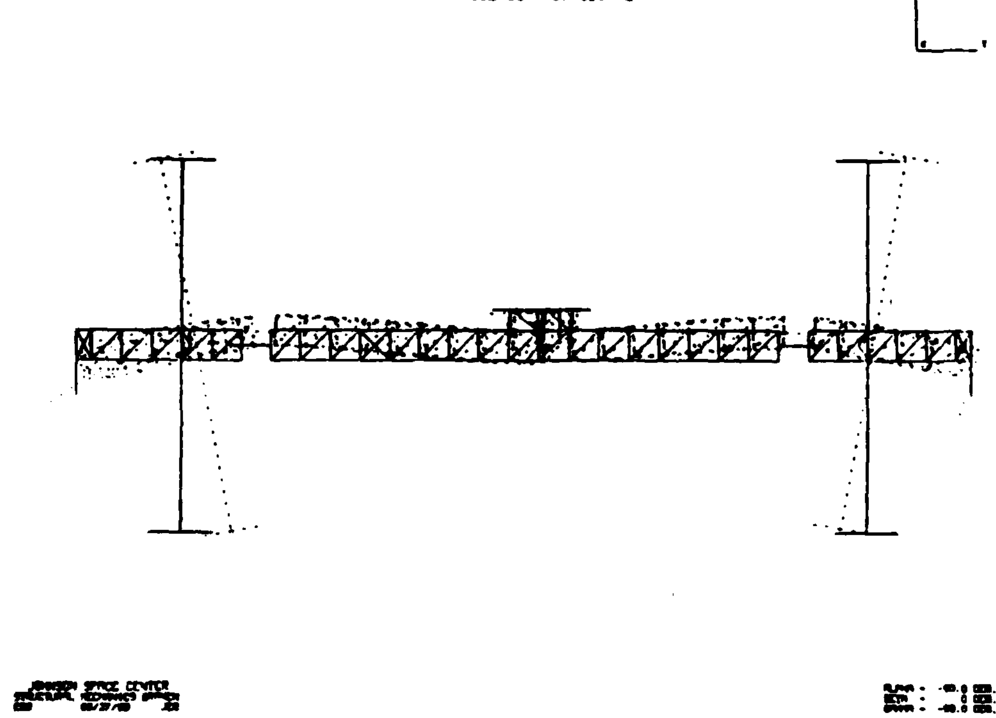

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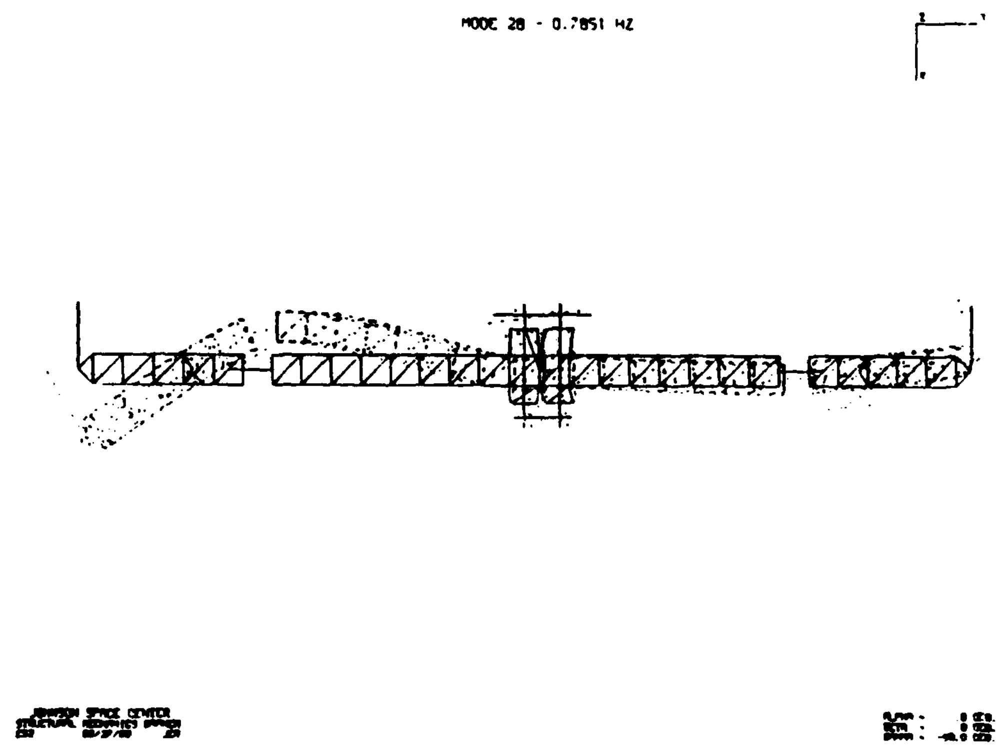

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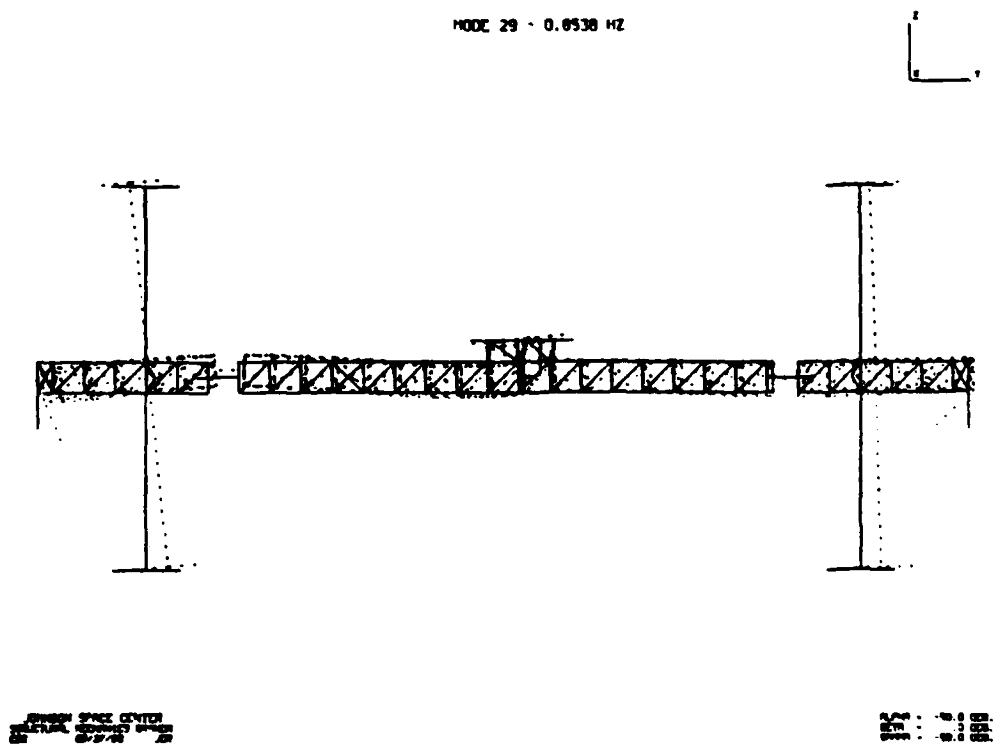

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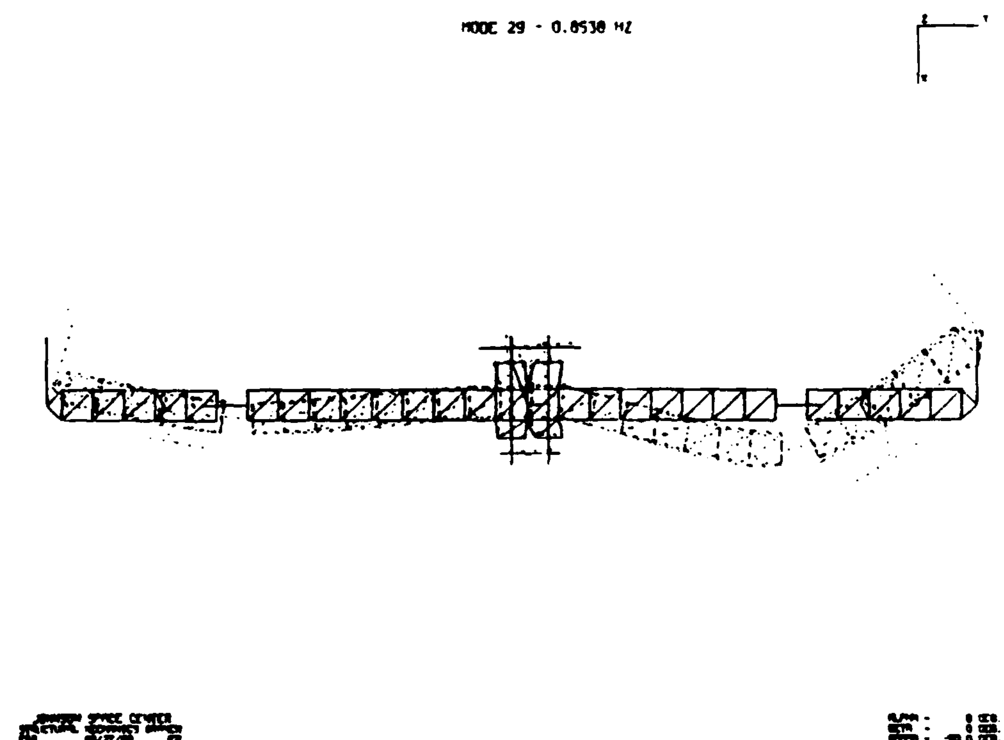

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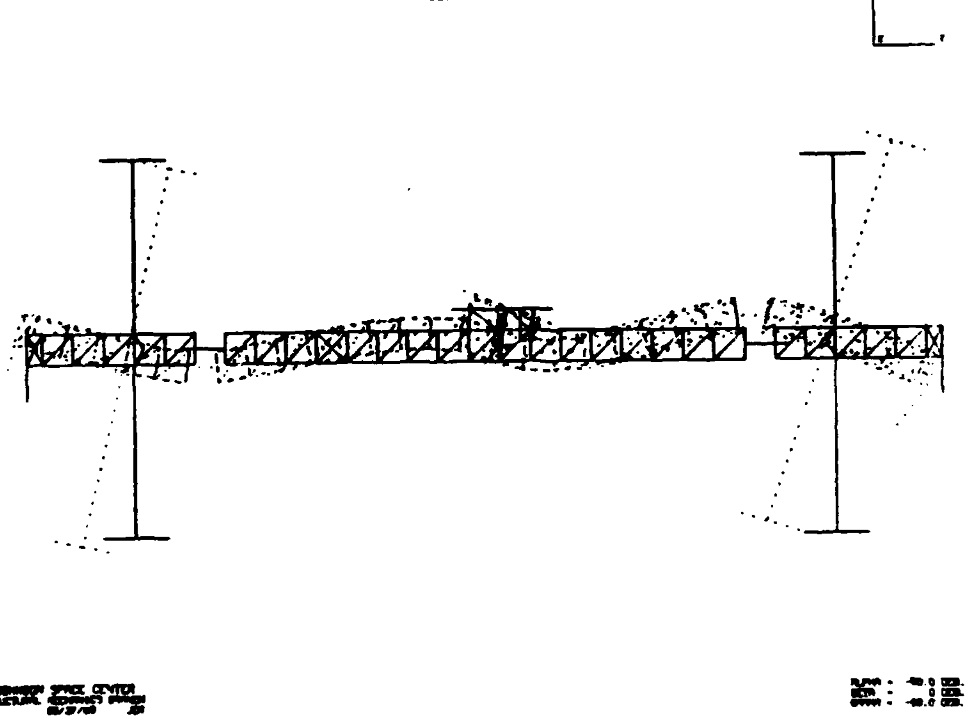

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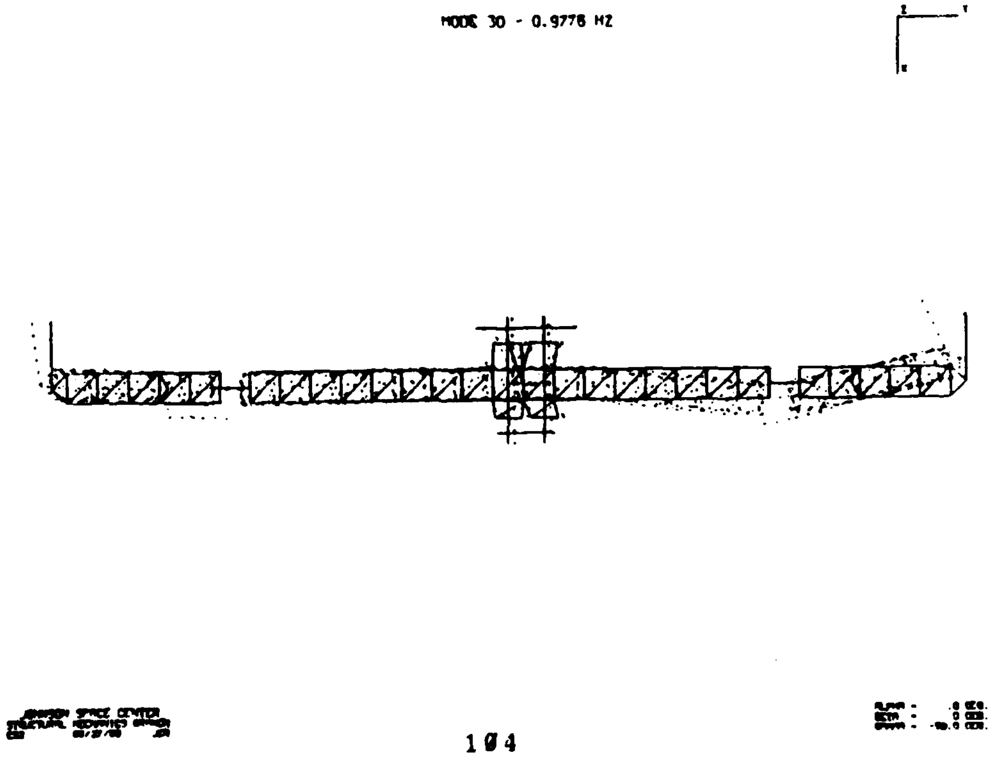

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Vita

Captain Dale A. Cope was born [redacted] He graduated from High School in Ennis, Texas in 1978. Receiving an Air Force Scholarship, he attended Texas A&M University as a member of the Corps of Cadets. He received his Bachelor of Science Degree in Aerospace Engineering in December of 1982. After graduating with Military Honors, he received a commission in the USAF through the ROTC program. He reported to Vandenberg AFB, California in March of 1983 to attend 4315th Combat Crew Training Squadron. Upon graduating, Captain Cope reported to his active duty assignment as a Missile Launch Officer at Whiteman AFB, Missouri, in June of 1983. He was quickly moved to the Instructor Shop for 351st Strategic Missile Wing. After-which, he was immediately upgraded to Missile Combat Crew Commander for the 510th Squadron. In May of 1987, Captain Cope entered the School of Engineering at the Air Force Institute of Technology. He is a member of the Air Force Association and Tau Beta Pi.

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Abstract: The major objective of this thesis is to apply a decoupled control technique to a specific space station model. The model is a finite element model of the Phase 1 Critical Evaluation Task Force (CETF) Space Station. The control technique allows for the active control of a large number of modes by using several decoupled controllers. The space station attitude control system provides attitude stabilization and disturbance rejection. Its performance is evaluated by the station's response to two disturbances - crew motion and shuttle docking.

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